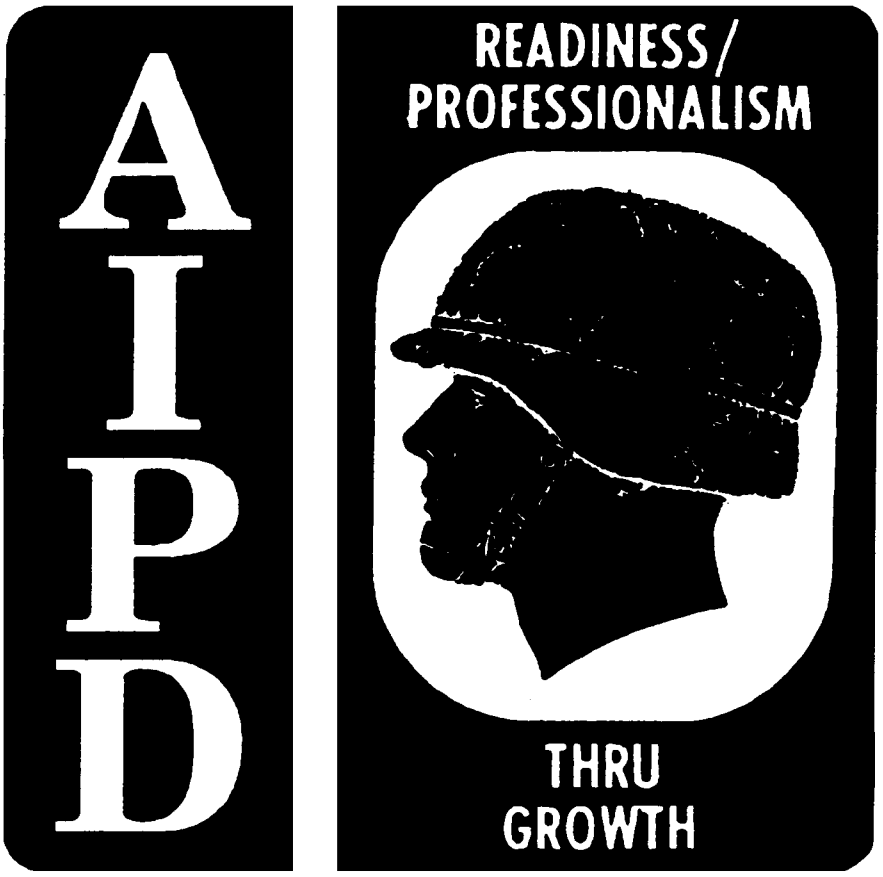
SUBCOURSE
MM0320

EDITION
6

COMMUNICATION FUNDAMENTALS



THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

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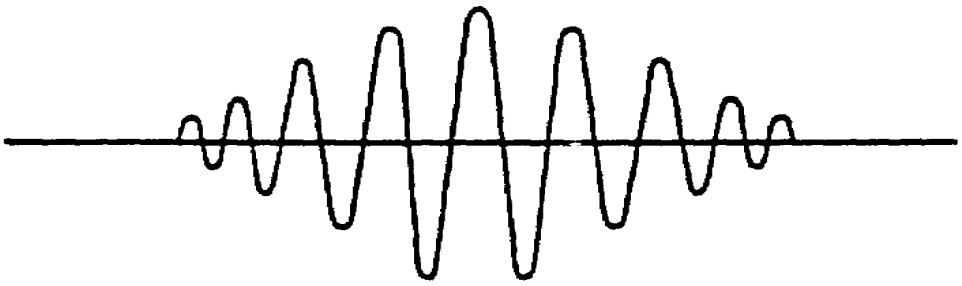

PLEASE NOTE

Proponency for this subcourse has changed

from Signal (SS) to Missile & Munitions (MM).

*** * * IMPORTANT NOTICE * * ***

THE PASSING SCORE FOR ALL ACCP MATERIAL IS NOW 70%

PLEASE DISREGARD ALL REFERENCES TO THE 75% REQUIREMENT.

SIGNAL SUBCOURSE 320, COMMUNICATION FUNDAMENTALS

INTRODUCTION

"Don't give me excuses," shouted the commander, "Give me communications." Your job as a signalman is to give the commander the communications he needs. However, it is not your job alone; two or more people communicate. Communication is a team effort that is complete only when your customer tells you he no longer needs the help you can give him. Your very reason for existence as a signalman is to provide communications to those who need it.

An effective communicator is one who knows the characteristics and limitations of all ordinarily available systems and equipment. Without this knowledge he is like a carpenter without a saw, a bricklayer without his trowel. Knowledge, expertise, and willingness to learn are the ingredients of the successful signalman.

This subcourse provides the background you will need to be an effective communicator. The Army can only provide this information to you; how you make the most of it is up to you. Properly used, this subcourse is the opening wedge to your future in communications. Use it wisely.

This subcourse consists of four lessons and an examination, as follows:

Lesson 1. Elements of Communication

Lesson 2. Telephone and Telegraph Communication

Lesson 3. Carrier Communication

Lesson 4. Radio Communication

Credit Hours: 5

You are urged to finish this subcourse without delay; however, there is no specific limitation on the time you may spend on any lesson or the examination.

Texts and materials furnished:

Subcourse Booklet

Special Text (IT) 11-180-8, Means of Communication (EXTRACTED)

You may keep the texts and materials furnished.

REVIEWED AND REPRINTED WITH MINOR REVISIONS FEB 76.

LESSON 1

ELEMENTS OF COMMUNICATION

SCOPE	Various means of communication; conveyance of information through communication processes; elements of an electronic communication system.
CREDIT HOURS	1
TEXT ASSIGNMENT	IT 11-180-8; Attached Memorandum, para 1-1 thru 1-6
MATERIALS REQUIRED	None
SUGGESTIONS	Study IT 11-180-8 and then the Attached Memorandum

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LESSON OBJECTIVES

When you have completed this lesson, you should:

1. Know that any of several means of communication may be used to send and receive messages.
2. Know that each of the several means of communication has its advantages and disadvantages.
3. Be able to identify the various means of communication.
4. Know that the end result of communication is transfer of thought.
5. Know that any means of communication consists of a source, a transfer medium, and a receiver.

ATTACHED MEMORANDUM

1-1. COMMUNICATION ACCURACY

One of man's characteristics is his ability to communicate ideas. Man has developed highly sophisticated methods to transfer ideas visually, orally, mechanically, and electrically. Whatever the method, the primary function of any communication system is to accurately transfer information. Distortion in the received sound or variation from the original printed word may affect the mental image formed by the listener or reader. It follows, therefore, that if communication between two people is to be successful, the precise order and form of the original sounds or words must be maintained during the information transfer process. All other system characteristics are secondary in importance to this function.

1-2. WORDS TRANSFER INFORMATION

A perfect communication system conveys information without modifying the original order and form of that information. However, a perfect communication system cannot compensate for the inability of the message originator to choose the correct words needed to accurately convey the intended thought. Neither can a correctly functioning communication system be held accountable for the failure of the listener or message reader to understand the message content. Technological advances have achieved great speeds of message transmission and reception. But our inability to express ourselves completely sometimes results in unexpected and undesirable communication delays. Often people have difficulty in communicating thoughts because the words they choose may not accurately convey the intended thoughts. The point being emphasized here is that no communication is complete until the receiving party acknowledges understanding of the message contents. Acknowledgment of receipt of the message does not in itself indicate nor guarantee that the message has been understood.

1-3. PICTURES TRANSFER INFORMATION

We all know from experience that a picture has the power to convey more information in less time and with greater accuracy than any other means of communication. This capability stems from the fact that what the eye sees, the mind interprets. The need for words to form the mental picture is thereby removed. If you want to experiment with this, try to describe in detail an electronic circuit or a weather map. Try as you might to be accurate, your listener will most likely form incomplete or inaccurate mental pictures from your word definitions. Transmission of pictures, maps, and diagrams by facsimile or television greatly enlarges the capability of military communication systems to transfer information. Pictorial transmission also has the ability to provide a "hard" or printed page copy. However, teletypewriter is a more practical means of providing a hard copy.

1-4. COMPONENTS OF SPEECH

Each of us has a characteristic speech pattern, and no two individuals speak exactly the same. The reasons for our speech being characteristically different are many and varied. A discussion of a few of these reasons will establish the need of a voice communication circuit to faithfully reproduce voice sounds. The principal determinants of voice characteristics are amplitude and frequency.

a. Amplitude. Amplitude is the loudness with which we speak. Some of us speak more loudly than others. Those who speak too loudly sometimes overload the amplifiers in communication systems and thereby destroy some of the voice quality by their own actions. Those who speak too softly will have difficulty being heard at the receiving end of the circuit.

b. Frequency. Frequency components in a voice signal are very complex. The combination of frequencies (pitch) in each voice gives it a characteristic sound. If an appreciable number of the frequencies that make up the voice sound are removed during signal transmission, we may have difficulty understanding the spoken words.

c. Individual Characteristics. Each of us has individual voice characteristics that identify us as precisely as our own name. Some of us speak slowly, others rapidly. Because of geographical differences in speech patterns, some of us pronounce words differently.

(1) The average communication system is not capable of reproducing speech exactly as it originated. Many systems are noisy. Therefore, the communicator must speak clearly and distinctly.

(2) Pronunciation of individual letters in the words has much to do with the ability of the listener to understand the message. Vowels are clearly discerned most of the time, but consonants are not easily understood because they are largely made up of high frequencies. If the communication system cannot pass these high frequencies, there is distortion.

(3) The phonetic alphabet is often useful when voice communications are weak or noisy. The phonetic alphabet is a system using words to denote letters. An entire word of the phonetic alphabet is given, the first letter of which expresses the letter in question. (Example: "Delta" to express the letter D.) Use of this alphabet allows positive identification of letters and reduction of errors and repetitions.

1-5. BASIC COMMUNICATION SYSTEM

a. Components. An electrical communication system must provide at least three basic components:

(1) An electromechanical device to convert information into electrical current variations. For example: telegraph key, microphone, facsimile scanner, etc.

(2) An electrical connection, or transmission system, which will convey the electrical variations to the distant point without altering their character greatly.

(3) An electromechanical device to convert the electrical current variations into mechanical or sound wave motion.

b. Information Feedback. Feedback is the response returned to the source to acknowledge understanding or provide requested information. A feedback system requires facilities for two-way transfer of information. Thus, a communication system is not complete unless it provides two-way communications.

1-6. SYSTEMS FOR INFORMATION TRANSFER

The basic communication systems used to transfer information are telephone, facsimile, and telegraph. Voice messages are transmitted over telephone circuits, visual images (photographs, maps, etc.) are transmitted over facsimile circuits, and teletypewriter messages are transmitted over telegraph circuits.

a. Telephone Transmission. The telephone system is an example of a simple electrical communication system. It consists primarily of a microphone, or transmitter, to convert sound waves to electrical signal, a transmission line

to carry the electrical signal, and a receiver to convert the electrical signal back to sound waves.

b. Advantages of Telephone Transmission.

(1) Most of us are familiar with telephone communication since we have used it in our homes for the greater part of our lives. Therefore we are able to use it with less specialized training than any other form of electrical communication.

(2) An immediate feedback channel exists to verify acknowledgment of understanding.

(3) Reduced to its operating essential, a telephone system is basically simple.

c. Disadvantages of Telephone Transmission.

(1) Messages sent by telephone are susceptible to inaccuracies. Most of these inaccuracies can be avoided, or at least minimized, by clear enunciation. Because of these inaccuracies, misunderstanding is an ever-present possibility.

(2) It is the least secure of the available methods of information transfer. Almost anyone with a suitable instrument can monitor the telephone conversation. Even with voice inverters, the security is not reliable.

(3) There is normally no record of the call and the discussion during the conversation. Thus, future action is difficult to build on the information transferred, and responsibility for the required action is therefore not established.

(4) The voice message is easily distorted by equipment or facilities over which the voice message passes. Noise and interference make the voice difficult to understand at times.

(5) The bandwidth of a telephone voice message is relatively large (normally about 300 to 3,500 hertz (Hz)). Therefore, the telephone system uses more frequency spectrum than narrowband systems such as teletypewriter.

d. Facsimile Transmission. Pictures, maps, and written pages can be transmitted by facsimile. The image to be transmitted is placed on the transmitting unit, where it is scanned by a photoelectric device. The photoelectric device detects shades of light and dark, and converts them to a varying electric current which is transmitted to the receiving unit. A pinpoint light in the receiving unit varies in intensity as a result of the varying electrical current, exposing a light-sensitive paper and thereby reproducing the transmitted image.

e. Advantages of Facsimile Transmission.

(1) For some purposes, photographs and drawings convey far more information in less time than word descriptions.

(2) Transmission of weather maps and military maps is especially important to military services.

(3) Facsimile signals can be successfully transmitted and received over any normal voice circuit.

f. Disadvantages of Facsimile Transmission.

(1) Transmission of visual images by facsimile is a relatively slow process. The speed of transmission is limited by the bandwidth capabilities of the interconnecting facilities. A normal telephone circuit passes a voice band from approximately 300 to 3,500 Hz, or, in other words, a 3,200-Hz bandwidth. This bandwidth limits facsimile transmission to a rate that allows the transmission of a weather map or large photograph in about 20 minutes. Insufficient bandwidth results in lack of contrast between light and dark shading.

(2) Facsimile images are subject to distortion by circuit noise and by interfering signals from adjacent lines. Noise causes spots and streaks to appear in the received image.

(3) Speed control of transmitting and receiving facsimile reproducers is a critical item. A synchronizing system helps to minimize this problem by including phasing pulses in the facsimile signal.

(4) The principal cause of "ghosts" or shadows in a received facsimile picture is phase delay of signal elements. Serious ghost interference of picture quality by the interconnecting lines requires that the lines be corrected by phase delay devices that counteract the delay characteristics.

g. Telegraph Transmission. Telegraph systems are utilized to transfer information in written form. A telegraph system is normally composed of a sending device which converts mechanical motion to dc pulses, a transmission path, and a receiving device which converts de pulses to mechanical motion.

h. Advantages of Telegraph Transmission.

(1) Teletypewriter communication produces a printed or "hard" copy. The most important characteristic of a hard copy is the printed record, which gives far more flexibility of use than a telephone voice message.

(a) A copy can be filed, and thus serve as a future source of reference if needed. Thus, dependence on human memory is minimized.

(b) Responsibility for the message and its contents can be positively identified by identifying the originator.

(c) Received messages can be acted upon at the appropriate time, or action may be delayed, as the situation warrants.

(2) By means of automatic sending devices, the messages can be sent at uniform speed to realize maximum efficiency of circuit operation.

(3) Messages can be routed through alternate channels.

(4) By the use of on-line security devices, messages can be automatically encoded and decoded during transmission and reception. This makes a teletypewriter circuit more secure than any other method of electrical communication.

(5) Precedence for message handling can be established. Messages can be arranged so that those of greater urgency can be sent with shorter delay time than those of lesser urgency.

(6) Automatic operation minimizes human error and individual characteristics in message transmission. If transmission is by automatic means, messages are placed on perforated tape. If procedure is correctly followed in message preparation, the "personal" touch given to electrical communication is minimized. Thus, there is less chance that the message transmission will disclose unit identification and tactical deployment.

(7) Voice frequency (VP) telegraph uses narrowband transmission. A large number of channels can be placed in the same spectrum occupied by a voice channel by using multichannel terminal equipment.

(8) Telegraph transmission, either dc or VF, minimizes the effect of noise. Until noise exceeds the pulse amplitude needed for character identification, it will have no effect.

(9) Telegraph distortion (shortening or lengthening of signal pulses) is not evident until it reaches the magnitude that results in misprinting. In other words, signal distortion is not noticeable in the message unless the distortion becomes so bad as to cause misprinting.

i. Disadvantages of Telegraph Transmission.

(1) Skilled people are needed to prepare the messages for transmission. Skilled people are also required for the process of message transmission and reception over the complete circuit.

(2) Teletypewriter messages lack the personal touch that telephone communication allows. Teletypewriter messages are cold, matter-of-fact communications.

(3) A relatively large equipment investment and inventory are required to achieve teletypewriter communication. This is especially true if multiple-channel operation is specified.

(4) A teletypewriter communication system is a complex arrangement, both as to system characteristics and equipment requirements. The complexity and multiplicity of equipment, especially in larger units, demand the use of an adequate maintenance organization.

LESSON EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. In tactical operations, no single means is best for communicating under all conditions in all situations. Whatever means is chosen, the foremost requirement is that it be

a. secure and reliable.
c. rapid and economical.
b. reliable and rapid.
d. economical and secure.

2. Tactical units may at times employ all forms of communication, including sound and visual. One characteristic common to both sound and visual communication is that they are

a. secure from enemy interception.
b. easily understood with little chance for error.
c. always effective under all battlefield conditions.
d. useful for transmission of prearranged short messages.

3. Panels are long strips of brightly colored or black-and-white material displayed by troops in the field for observation by aircraft. Panels are used to

a. mark positions, identify friendly units, and send brief messages.
b. identify friendly units, send brief messages, and marking targets;
c. send brief messages, identify enemy units, and mark positions.
d. identify enemy units, mark positions, and send brief messages.

4. Assume that a tactical radio operator has to transmit an important message a long distance through strong interference. Since slow speed is essential in such case, the recommended method for transmission of the message is

a. AM.
c. CW.
b. FM.
d. PM.

5. The electrical/electronic communication methods include

a. visual, voice, television, and data.
b. sound, telegraph, facsimile, and visual.

c. teletypewriter, sound, data, and television.

d. voice, telegraph, teletypewriter, and facsimile.

6. The primary function of any communication system is to accurately transfer

a. words.
c. pictures.

b. voice.
d. information.

7. Communication between two parties is considered to be complete when the

a. receiving party acknowledges understanding of the message content.

b. receiving party acknowledges receipt of the message.

c. receiving operator records the message.

d. sending operator sends the message.

8. You can make yourself better understood over a telephone by controlling certain characteristics of your voice. The principal voice characteristics you can control that have a bearing on this understanding are

a. loudness and pitch.

b. pitch and geographical speech patterns.

c. nasal sounds and letter pronunciation.

d. geographical speech patterns and nasal sounds.

9. Assume that you are choosing code words for telephone station identification from a list including the following: MANNER, SISTER, DOGWOOD, and DANGER. The code word that will be <u>most</u> affected by loss of high frequencies on the telephone circuit is

a. DANGER.
c. MANNER.

b. SISTER.
d. DOGWOOD.

10. An electromechanical device is needed at the sending end of an electrical communication system because it must

a. convert information into electrical current variations.

b. convert electrical current variations to mechanical motion.

c. provide an electrical transmission path to the distant station.

d. convey the electrical variations to the distant point without altering the signal characteristics.

11. Assume that you are to transmit information from a situation map regarding tactical deployment of units. The method of transmission that can convey the desired information in minimum time and with maximum accuracy is

a. radio.
b. telephone.
c. telegraph.
d. facsimile.

12. A simple communication system, such as a telephone system, consists of three basic parts. These parts are:

a. receiver, battery, and feedback link.
b. transmission line, receiver, and battery.
c. transmitter, transmission line, and receiver.
d. feedback link, transmitter, and transmission line.

13. One advantage of a telephone communication system over other types of communication systems is that it

a. requires less time to convey the message.
b. provides the most accurate means of communication.
c. permits everyone who wants an instrument to have one.
d. allows transfer of information in a form that everyone understands.

14. In the event that you must send a classified message, you should NOT send it over the telephone because

a. the voice message is easily distorted.
b. there is too much possibility of error.
c. the time required for transmission is too great.
d. a telephone system is the least secure of all wire communication systems.

15. One of the characteristics of a facsimile transmission system is that

a. requires no synchronization.
b. is a high-speed method of transmission.
c. can operate over any normal voice channel.
d. is free from the effects of noise and interference.

16. Assume that "ghosts" or shadows appear in a facsimile picture you have received, the principal cause of this trouble is

a. speed difference.

b. lack of synchronizing pulses.

c. phase delay of signal elements.

d. insufficient bandwidth of interconnecting line facilities.

17. Maximum efficiency of a telegraph transmission system is obtained by using automatic sending devices because

a. messages can be sent at uniform speed.

b. messages can be routed through alternate channels.

c. a copy of the message can be recorded for file purposes.

d. automatically encoding and decoding on-line security devices can be used.

18. One of the advantages gained by using a teletypewriter transmission system is that

a. automatic equipment minimizes human error.

b. simplified circuit arrangements reduce installation time.

c. unskilled operators can pass traffic over the circuit efficiently.

d. the small quantity of equipment minimizes the maintenance problem.

19. A voice-frequency telegraph system is inherently a narrowband system. This fact means that a telegraph system is

a. inflexible in its operation.

b. free from telegraph distortion.

c. efficient in the use of voice-band spectrum.

d. limited to slow speed transmission and therefore inefficient.

20. One characteristic of a telegraph carrier system is its low noise effects. Noise effects are minimized because

a. narrowband transmission limits the noise frequencies.

b. wideband transmission allows for reception of maximum signal strength.

c. noise is distributed equally over a large number of narrowband channels.

d. noise is not noticed until it exceeds the pulse amplitude needed for character identification.

CHECK YOUR ANSWERS WITH LESSON #1 SOLUTION SHEET, PAGE 46.

LESSON 2

TELEPHONE AND TELEGRAPH COMMUNICATION

SCOPE	Simple telephone circuits; characteristics of telephones and connecting lines; function of telephone switchboards; principles of telegraph transmission.
CREDIT HOURS	1
TEXT ASSIGNMENT	Attached Memorandum, para 2-1 thru 2-6
MATERIALS REQUIRED	None
SUGGESTIONS	None

LESSON OBJECTIVES

When you have completed this lesson, you should:

1. Know that a telephone communication system is made up of smaller subsystems or circuit components.

2. Know that a switchboard provides interconnection capability between subsystems and circuit components.

3. Be able to compare the characteristics of manual and dial telephone systems.

4. Be able to compare common-battery and local-battery telephone systems.

5. Know that ac telegraph devices permit information from dc telegraph signals to be transmitted over a telephone circuit.

ATTACHED MEMORANDUM

2-1. THE TELEPHONE SET

Every telephone set contains three basic elements: a transmitter (microphone), a receiver (earpiece), and a sounder (bell or buzzer). The microphone generates the voice currents, and the earpiece converts the voice currents back to sound waves. These two elements therefore operate on electromagnetic principles. The bell or buzzer signals the desired party. Some telephones are equipped with a handcranked generator to develop signaling voltage.

2-2. TELEPHONE SYSTEMS

a. A Simple Telephone System. A simple telephone system consists of two telephone sets connected by a pair of wires. Voice currents developed in the microphone of one telephone set travel over the connecting wire and excite the earpiece of the distant telephone set. The sound reproduced by the earpiece conveys the message to the listener. The return circuit uses an identical

system of microphone, wire, and earpiece. Such a telephone circuit, although simple, lacks flexibility of operation. As soon as additional telephones are connected to this simple circuit, the users of the system interfere with each other. To prevent this interference and to achieve flexibility of operation, switchboards are inserted in the lines between the telephones. Dc voltage is needed to furnish transmission power in most telephone systems. This dc voltage may be furnished either by the switchboard or by the individual telephones. When power is furnished by the switchboard, the system is called a common-battery system. When power, usually batteries, is furnished by the individual telephones, it is called a local-battery system.

b. A Multistation Telephone System. A switchboard or other switching device is usually located at a telephone central office. A telephone system with one central office consists of a number of telephone stations connected by lines to the central office, so that any two telephones of the system may be connected for two-way conversation. Such a system may serve a few stations or thousands of stations. A complete multistation telephone system includes the individual telephone stations, outside plant equipment, central offices, and transmission lines.

(1) The outside plant equipment consists of the interconnecting transmission lines and support facilities such as poles or underground conduits.

(2) Central offices include all the equipment required for making connections between the telephones and the switchboards, and for making connections between associated switchboards.

(3) Transmission lines used to connect telephones to switchboards are called local lines, while the transmission lines interconnecting switchboards are called trunks.

2-3. THE TELEPHONE SWITCHBOARD

a. Telephone System Without a Switchboard. A telephone system frequently consists of hundreds, even thousands, of telephone stations. In operation, the system permits voice communication between any of the telephone stations which are part of it. Without a switchboard, all of the stations in the system would be tied together with a maze of wires, as shown in figure 2-1. It is apparent from this figure that whenever one person is talking, everyone else must listen. If a second user of the system desires to direct his message to a different telephone, confusion due to interference is bound to result. In spite of the handicap of this type of system, it still finds use in a conference network, wherein all parties can hear any one speaker, and each speaker in turn may talk.

b. Telephone System Having a Switchboard. An important saving in wire is obtained by including in the system a centrally located switchboard, as shown in figure 2-2. Each telephone station is then connected directly to the switchboard, not to any of the other telephone stations. The connecting wires and their attachments constitute a transmission line. Conversation between any two stations without interference with the others is made possible by connecting their transmission lines at the switchboard. The connections are made by a switchboard operator or attendant by means of connecting (switchboard) cords.

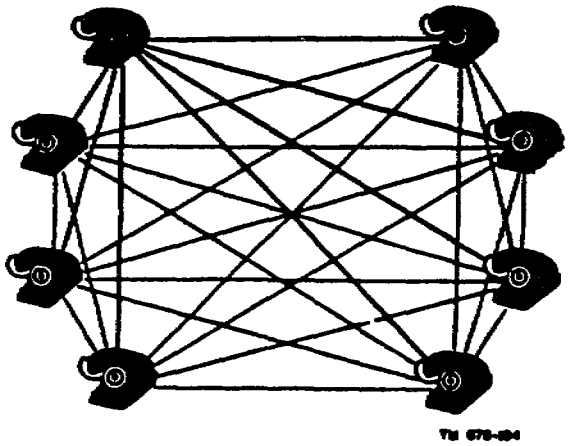

Figure 2-1. Station interconnections of a telephone system without a switchboard.

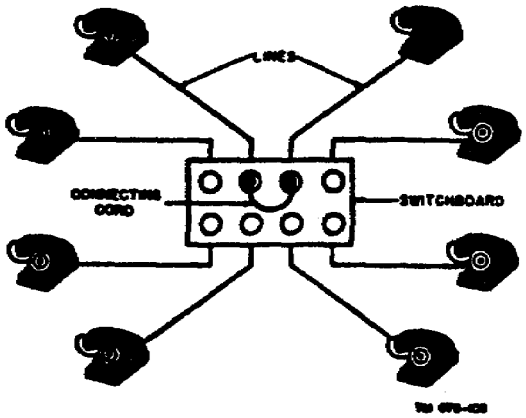

Figure 2-2. Telephone stations connected to a switchboard.

c. Telephone Signaling. A local-battery telephone can signal another one with a handcranked generator, and can also manually signal a switchboard with the generator voltage. On the other hand, a common-battery telephone is limited to signaling the switchboard; it ordinarily cannot signal another telephone.

(1) Local-battery switching. When a telephone user turns his handcranked generator, the voltage causes a switchboard "drop leaf" to fall, indicating to the operator that a call is arriving. The operator then patches the line and rings the called party with a switchboard-generated voltage.

(2) Common-battery switching. When a telephone user lifts his handset from the telephone instrument, a "supervisory" light automatically glows in the switchboard, alerting the operator that a call is arriving. The switchboard operator then patches the line and rings the called party with a switchboard-generated voltage.

2-4. COMPARISON OF TELEPHONE SYSTEMS

a. Comparison of Manual and Dial Telephone Systems. Telephone communication systems used by the US Army must provide good telephone service under many kinds of operating conditions, both favorable and unfavorable. Both manual and dial systems are used. Each system has its advantages and under certain conditions provides better service than the others. Each telephone system therefore has an important place in the military communications network. In general, dial systems are less suitable than manual systems for mobile operations and usually are installed only at more permanent locations, such as posts and the larger headquarters in the rear area of a theater of operations.

b. Manual Systems. Military field telephone systems must be mobile; they consequently use manual switchboards. These switchboards may be either the local-battery or common-battery type.

(1) Local-battery. In a local-battery telephone system, each telephone furnishes its own battery power. The switchboard serves merely as a switching point in the system. This is a simple system used primarily in forward areas.

(2) Common-battery. In a common-battery telephone system, all telephones draw their battery power from the switchboard to which the telephones are connected. This is a more refined system used in rear areas.

c. Local Lines and Trunks. A military local-battery field telephone system usually has rapidly laid insulated wire or cable for its lines and uses manual central office equipment of sturdy construction. The hand generator used for signaling provides a greater distance range in ringdown signaling capability than in the common-battery system. Therefore, the local lines may be longer. A local line usually refers to the wire leading from a switchboard or central office to a subscriber's telephone, while a trunk refers to the wire connecting two or more central offices.

d. Refinements. The common-battery manual telephone system is used most frequently to serve a large number of telephone users located in a relatively small area. It has numerous refinements, not found in the simple local-battery systems, which make possible more efficient and rapid handling of large numbers of calls. Because of these refinements, however, a common-battery central office with its associated lines requires more time for installation and greater attention to maintenance. Common-battery manual systems are normally used by corps and higher headquarters.

e. Dial Systems. In dial telephone systems, which are also common-battery, the use of automatic switching devices eliminates the errors inherent in human operation of a manual telephone switchboard. A dial central office requires much intricate wiring and complex equipment. Its installation is both time consuming and costly. It requires great care in maintenance, but when properly maintained it provides more rapid and accurate circuit switching and traffic capability than is normally possible with a manually operated common-battery switchboard.

f. Flexibility. To provide greater flexibility for military operations, practically all common-battery switchboards are designed to permit connections with local-battery switchboards and telephones. The larger local-battery switchboards further enhance this flexibility by allowing for connections to common-battery switchboards, both manual and dial.

2-5. DC TELEGRAPHY

Dc systems of telegraph transmission fall into two fundamental classes - - neutral and polar. All other systems of dc telegraph transmission, no matter how complex, are basically variations of neutral or polar systems. All teletypewriter systems are merely variations of mechanical telegraph systems wherein the de marking and spacing Signal pulses occur at stated keying rates. Teletypewriter signals are fundamentally telegraph signals arranged for mechanical transmission and reception. In all discussions to follow, therefore, teletypewriter operation will be treated as telegraph operation.

a. Neutral Operation. In the neutral telegraph system, transmission is accomplished by sending peak current over the line for intervals of time corresponding to marking signals, and interrupting the current for intervals corresponding to spacing signals. Peak current is the normal maximum value of current on which the circuit is designed to operate.

(1) The neutral telegraph system is used mostly for short lengths of transmission line, because long transmission lines distort the telegraph pulses. This pulse distortion is caused by reactive line constants of inductance and capacitance. Although resistance tends to reduce the amplitude of the pulses, resistance alone does not distort the telegraph pulses.

(2) The neutral system requires little in the way of terminating equipment, and is easy to install and to operate. It is simple, and generally requires a minimum of system maintenance.

b. Polar Operation. Polar operation differs from neutral operation in that telegraph signals are formed by reversing the direction of the current flow to a receiving polar relay instead of interrupting the current flow. In other words, polar operation uses a flow of current in one direction over the line to operate the receiving relay armature to the marking position, and a flow of current equal in value but opposite in direction to operate the armature to the spacing condition. It is this sensing of current pulses by relays that complicates the circuitry. Although the polar system is more complex than the neutral system and requires more equipment for its operation, its signal is not adversely affected by line constants (resistance, inductance, capacitance) to the same degree as neutral signals. This results from the fact that signal pulses consisting of oppositely flowing current are affected similarly by the line's electrical characteristics. Since line constants generally do not distort polar signals at normal teletypewriter code speeds, their use is not usually limited by line length (within limits). To say this another way, polar signals can be successfully transmitted and received over much longer lines than is the case with neutral signals.

c. Modes of Operation. Two modes of operation generally used in teletypewriter systems are half-duplex and full-duplex.

(1) Half-duplex is the simpler of the two modes. It permits transmission of messages in either direction on the same line, but not in both directions simultaneously. It also permits the feature of break-in, whereby the receiving operator can interrupt the transmission of the sending operator.

(2) The full-duplex mode permits transmission of messages in two directions simultaneously. This mode of operation can handle more traffic than the half-duplex mode because traffic moves continually in both directions. It normally requires the use of two separate paths, one for each direction of transmission. Unless specifically engineered into the system, a full-duplex mote of transmission does not allow one operator to interrupt (break) the other operator.

2-6. AC TELEGRAPHY

In ac or VF telegraph systems, a carrier frequency is provided for each channel. This carrier is made to conform to the pattern of the telegraph

signals by a process of modulation (keying of a tone oscillator). This process is initiated at the sending end of each circuit by operation of the telegraph sending equipment, which originates signals in the form of dc pulses. Subsequent to modulation, the keyed tone or ac signal conveys the intelligence over the transmission line. At the distant end, the pulsed ac carrier signals are demodulated (restored to direct current) for actuation of the telegraph receiving instrument. The ac system usually can be operated over any good telephone line or radio circuit. The advantage of the ac or keyed tone system over the dc system is the fact that the keyed tone signals can convey information over long lines without being distorted by line constants. In addition, tone telegraph terminal equipment is available in either single-channel or multichannel configurations. The terms ac telegraph, tone telegraph, and VF telegraph are synonymous.

a. On-Off Keying. The on-off method of VF keying is the oldest ac telegraph system devised. It is still used on short lines and on radio systems having low noise levels. The on-off system keys or modulates a constant-frequency tone with the telegraph pulses, normally sending tone for mark and no tone for space. Although the system has a simple equipment configuration, it is hampered in its operation by the noise level which usually rises during the no-tone interval.

b. Frequency-Shift Keying. The method most generally used for VF teletypewriter operation is to shift the carrier slightly between two different frequencies, one frequency representing mark and the other frequency representing space. This is known as the frequency-shift-keying (FSK) method. The receiving equipment converts these FSK signals to dc signals which, in turn, actuate the receiving teletypewriters. The FSK system is directly applicable to both radio and wire circuits. Its advantage over the on-off keying method for radio transmission is that noise buildup is held to a minimum, since a signal is always present. The same advantage also accrues on long-distance wire circuits, where noise my rise to an appreciable value of signal amplitude.

c. Telegraph-on-Telephone. It is possible to combine both an FSK telegraph signal and a telephone signal on the same line without causing mutual interference, by using a "speech-plus-duplex" system. This system mates use of a narrowband filter that removes from the speech channel a 250-Hz band for use by the tone telegraph channel. There is some degradation of signal quality, but not enough to hinder normal speech communication. Since both terminals produce the same tone frequencies in the FSK signals, each operator must take turns using the line facility. This gives rise to the one-way reversible mode of transmission, which is the mode of transmission most often used in speech plus duplex.

STUDY EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. Flexibility of operation in a telephone system is obtained through the use of

   a. switchboards.
   b. parallel lines.
   c. local batteries.
   d. common batteries.

2. The function of trunks in a multistation telephone system is to interconnect

   a. each telephone station to the central office.
   b. outside plant equipment to the central office.
   c. telephones to switchboards.
   d. central offices.

3. The diagram of a telephone network without a switchboard is shown in figure 2-1. One characteristic of this network is that

   a. any station can selectively call any other station.
   b. all the telephones are connected in series with each other.
   c. traffic can move freely between all stations because of the wire maze.
   d. the signal from one telephone will be heard in all earpieces simultaneously.

4. In a common-battery telephone system, signaling is performed by the operator located at the

   a. switchboard.
   b. outside plant.
   c. telephone station.
   d. transmission line termination.

5. Telephone operators normally connect telephone stations together by using

   a. binding posts.
   b. toggle switches.
   c. switchboard cords.
   d. plug-in terminal blocks.

6. Conservation of field wire is an important logistical consideration. The component in a telephone system that aids in conserving wire is the

   a. signaling device.
   b. telephone switchboard.
   c. local-battery telephone.
   d. common-battery telephone.

7. Various types of switchboards have their recommended uses in military communications networks. When mobility is a prime consideration (as in forward areas), the choice of switchboard type should be

a. automatic dial.
c. manual local battery.
b. semiautomatic cord.
d. manual common battery.

8. Local lines in some local-battery telephone systems can be longer than those in common-battery systems because the

a. line battery voltage is greater.
b. telephone earpiece is more sensitive.
c. hand generator provides greater signaling range.
d. loop resistance is less than the trunk resistance.

9. A headquarters at which a common-battery central office is normally used is

a. corps.
c. infantry brigade.
b. armor battalion.
d. infantry division.

10. Assume that you are comparing the characteristics of a manual telephone system with those of an automatic dial telephone system. One advantage of the automatic dial system over the manual system is that the automatic dial system

a. requires far less maintenance.
b. provides more rapid and accurate circuit switching.
c. reduces the amount of complex equipment needed for system operation.
d. minimizes intricate wiring and therefore reduces installation time.

11. One reason that small common-battery switchboards are arranged to permit connections to local-battery switchboards and telephones is to achieve

a. centralized ringing.
b. flexibility of operation.
c. compatibility with dial systems.
d. increased distances of transmission.

12. A telegraph signal wherein current pulses vary from zero to a stated (peak) value is known as

a. polar.
c. marking.
b. neutral.
d. spacing.

13. The neutral telegraph system is used mostly for short transmission lines because

a. break signals are effective only on short lines.

b. reactive constants of long transmission lines distort the telegraph pulses.

c. short transmission lines minimize the complexity of system configuration.

d. resistance in long transmission lines causes signal pulse distortion.

14. A polar telegraph system requires the use of complex equipment because

a. signal pulses must be sensed by a receiving polar relay.

b. a break system is required to interrupt the current flow.

c. signal pulses consisting of oppositely flowing current are affected differently by line constants.

d. special components must be included to overcome the effects of telegraph distortion caused by line constants.

15. What is one characteristic of the output signal from any VF telegraph transmitting terminal that is passing traffic?

a. The signal amplitude never varies.

b. The signal always shifts frequency.

c. The signal is modulated by dc pulses.

d. The frequency of the signal always remains constant.

16. Although the on-off keying method of ac telegraphy is basically simple, its operation is hampered by its

a. slow speed of transmission.

b. dependence on the type of dc loop.

c. rising noise level during no-tone intervals.

d. changes in signal level from tone to no-tone intervals.

17. The method generally preferred for tone telegraphy (teletypewriter) consists of

a. keying the carrier on for mark and off for space.

b. keying the carrier on for space and off for mark.

c. varying the carrier amplitude in accordance with pulse amplitude changes.

d. shifting the carrier to one frequency for mark and another frequency for space.

18. One method of telegraphy that gives equally satisfactory operation in wire as well as in radio communication is

a. dc polar.

b. dc neutral.

c. ac on-tone, off-tone.

d. ac frequency-shift keying.

19. The transmission mode most often used by speech-plus-duplex systems is one in which the

a. two terminals use the line alternately.

b. two terminals send in both directions simultaneously.

c. one terminal keys for mark signals and the other one keys for space signals.

d. one terminal shifts the phase of its signal to permit transmission in two directions.

20. In the speech-plus-duplex system, tone telegraph signals do not interfere with the speech signal because of the

a. mode of operation.

b. narrowband filter.

c. dissimilar frequencies of the two terminals.

d. separate lines for speech and tone telegraph signals.

CHECK YOUR ANSWERS WITH LESSON #2 SOLUTION SHEET, PAGE 47.

LESSON 3

CARRIER COMMUNICATION

SCOPE..... Combining of communication channels on a common line; frequency translation; telephone and telegraph multiplexing principles.

CREDIT HOURS..... 1

TEXT ASSIGNMENT..... Attached Memorandum, para 3-1 thru 3-9

MATERIALS REQUIRED..... None

SUGGESTIONS..... None

LESSON OBJECTIVES

When you have completed this lesson, you should:

1. Know that several channels of communication can be combined on a pair of wires by the process of multiplexing.

2. Know that an integrated communication system includes multiplexing carrier terminals together with radio relay sets.

3. Know that a radio system and a carrier system operate on similar principles but different frequencies.

4. Be able to analyze a block diagram of an integrated communication system.

5. Be able to distinguish the difference in operating principles between frequency-division and time-division multiplex.

ATTACHED MEMORANDUM

3-1. CARRIER PRINCIPLES

Nearly all types of electrical communication systems use the carrier communication principle in one form or another. Depending on the traffic requirements, the terminals may be single-channel or multichannel. In most cases the carrier frequency is supplied by an oscillator. Whatever the frequency chosen for the carrier, it should be at least 10 times the highest frequency used for modulating it. The interaction of the carrier and modulating frequency produces an amplitude-modulated frequency-modulated or phase-modulated signal, depending on the system design. In the receiving process the sequence is reversed, the signal intelligence being extracted by demodulation. System characteristics of any carrier system are to a large extent determined by the carrier frequency.

a. High-Frequency Carriers. Radio-frequency carriers occupy the frequency spectrum above approximately 20,000 Hz and are therefore classed as high-frequency carriers.

b. Low-Frequency Carriers. Low-frequency carriers (below 20,000 Hz) will not radiate and are therefore usually transmitted over wire or cable facilities. They can be transmitted over radio systems by modulating the radio-frequency carrier.

3-2. COMPARISON OF RADIO AND CARRIER SYSTEMS

a. Radio System. A radio system is a communication system in which the carriers or their modulation products, or both the carriers and modulation products are transmitted through space by electromagnetic radiation.

(1) Power. Much of the transmitted power in a radio signal is not usable because it is radiated in many directions in addition to the intended direction toward the receiver site. The signal loss is smaller in a radio relay system because directional antennas restrict the radiated signal to a narrow transmission path. There is always a loss caused by signal power absorption in the radio transmission path. Likewise, landline carrier is still more efficient because the signal path is enclosed within the cable.

(2) Capacity. A radio system is capable of transmitting one signal at a time. If we were to direct more than one telephone or switchboard line toward a distant location, a separate radio frequency (RF) would be needed for each channel of communication. A discrete RF would have to be assigned for each RF carrier. Individual radio transmitters and receivers for each channel of communication would also have to be provided.

b. Carrier System. By popular usage, "carrier system" designates a communication system in which the carriers or their modulation products, or both carrier and modulation products are transmitted over wires or cables. It is in this sense that the term will be used throughout this course.

(1) Power. Loss of signal power in a carrier system is due primarily to line constants of induction, capacitance, and resistance. It is convenient to lump these values into one quantity called line attenuation. Line attenuation plus losses induced by reflection of the signal are categorically labeled line characteristics. These components that make up line characteristics therefore determine to a large extent the efficiency of carrier communication systems. Since the line characteristics can be engineered out of the system, the efficiency of power transfer is consequently high.

(2) Capacity. The traffic-handling capacity of a carrier system is primarily limited by the interconnecting line or cable and the facilities. Each signal modulates a different frequency within a group of frequencies provided by the carrier system. The number of frequencies that can be modulated depends on the signal bandwidth and the frequency bandpass of the interconnecting line or cable. Telephone carrier systems usually handle up to 16 telegraph channels on one voice channel.

c. Combined Carrier and Radio. In situations where the use of wire lines becomes an inconvenience, such as during tactical operations, it becomes necessary to use a radio system to carry a composite carrier signal. The bandwidth occupied by the composite carrier signal (baseband) becomes an integrated part of the transmitted radio spectrum. The bandwidth of the radiated signal in turn depends on the number of carrier channels being provided.

3-3. INTEGRATED COMMUNICATION SYSTEM

a. Formulation. An integrated radiotelephone communication system is shown in figure 3-1. This diagram illustrates how to expand traffic capacity of an existing radio facility by superimposing one device on another, using the building-block principle. In establishing the system, a telephone carrier terminal is first superimposed on the radio system, and the necessary telephones are then added to the system terminations. Greater message capacity is obtained secondarily by placing the signal from a telegraph carrier terminal on one channel of each telephone carrier terminal. Attachment of the teletypewriters to the telegraph carrier completes the overall system.

b. System Operation. At each termination of the composite radio system, four teletypewriters together with two telephones send and receive the message information. Messages from four teletypewriter terminal channels (A, B, C, D) are combined, or multiplexed, on a telegraph carrier terminal. This four-channel information is transmitted over one channel (channel 4) of the telephone carrier terminal. The facsimile signal occupies channel 3 of the telephone carrier terminal, while two telephone voice messages occupy channels 1 and 2.

3-4. FREQUENCY-DIVISION MULTIPLEXING

In a frequency-division-multiplexing (FDM) system, one amplitude- or frequency-modulated signal is transmitted in a certain definite frequency band, and another signal is transmitted in a neighboring band above or below the first signal. Additional bands can be added within the limitations of the transmission facilities. The frequency bands representing the individual channel signals are selected from the composite at the receiving terminal by channel filters. Each channel signal is distinguished from all others by the frequency band it occupies. The final demodulation removes the intelligence from the channel signal with a locally generated carrier which must be as close as possible to the modulating carrier frequency.

3-5. TIME-DIVISION MULTIPLEXING

Time-division multiplexing (TDM) may be explained as follows: Assume that signals from four VF telephone channels are to be sent by pulse-modulation methods. The modulating equipment is designed to sample all four signals, taking a sample from each of them in succession before returning to the first one. The sampling rate must be four times as fast as would be needed to send one signal, so that each signal is sampled often enough for satisfactory transmission. At each sampling, a pulse or group of pulses is created which registers the amplitude of the sampled signal at that moment. Thus, bits of information from all four signals are sent in rotation by one chain of pulses. At the receiving end, the pulses are sorted out and returned to their respective signal.

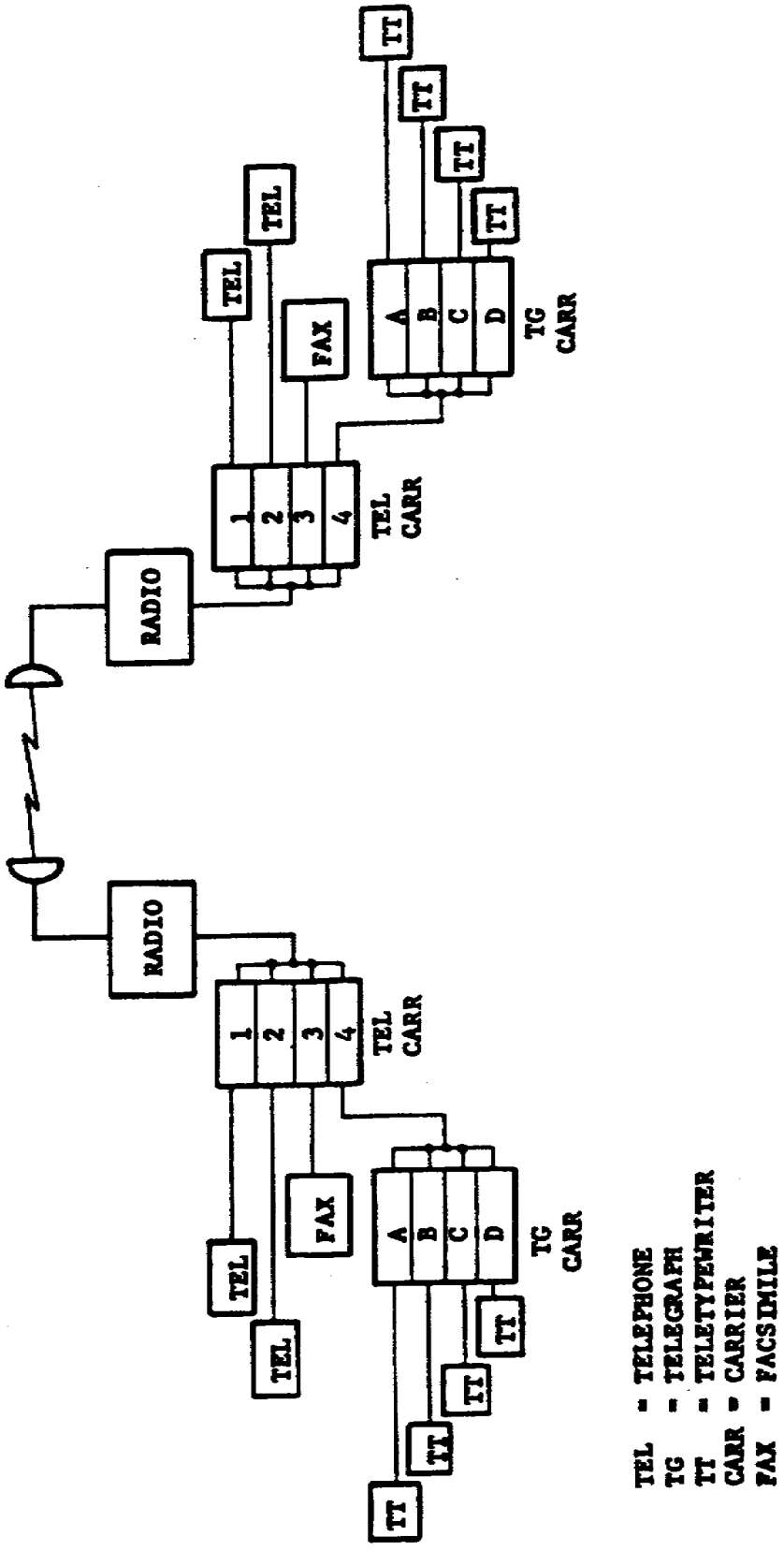

Figure 3-1. An integrated communication system.

3-6. CHANNEL SEPARATION

When several channels are transmitted over one facility (usually wire, cable, or radio), provisions must be made to prevent interference from nearby channels. To achieve channel separation, FDM and TDM employ different processes.

a. Channel Separation in FDM. The amount of separation required between adjacent FDM carrier channels depends on the characteristics of the filters used to separate the channels. A filter with a sharp cutoff can be used with narrow channel separation; a filter with a gradual cutoff requires a wider separation. The separation between channels is called a guard band. There must always be a guard band to give a margin of safety against mutual interference.

b. Channel Separation in TDM. Each pulse in the rapidly cycling pulse train represents one channel of communication. The sending and receiving terminals must be completely synchronized to insure the return of each pulse to the correct channel. Failure to synchronize equipment will cause garble to appear in the receiving channels. Channel separation depends on the cycling rate of the equipment and the number of channels in operation.

3-7. EQUALIZATION AND AMPLIFICATION

a. Equalization. In a correctly operating carrier system, all channel signals are applied to the line at approximately equal levels. If the line characteristics are entirely uniform, the received signals will exhibit the same proportion of signal strengths, although reduced in power. However, the line characteristics will not permit this desirable condition to exist. The highest frequencies will be attenuated (reduced in power) the most, with the lowest frequencies being affected the least. The solution to the problem is to insert at the receiving terminal electrical characteristics that will present to the incoming signals a mirror image of line characteristics. The net result is a leveling out of all received signal strengths. An amplifier is then needed to raise the received line signals to the level required for use in the receiving terminal.

b. Amplification. Power loss in the line reduces the useful received power. Amplifiers are used to raise the power level so as to compensate for line loss. Line amplifiers, called repeaters, are placed at strategic points along the line or cable to compensate for line loss in each unit length of cable or line. The unit length depends on the loss characteristics of the cable or line. An amplifier must also follow each equalizer, because an equalizer always introduces loss.

3-8. BANDWIDTH REQUIREMENTS OF CARRIER

a. Channel Signal. The bandwidth of a given channel of carrier is related to the type of intelligence being transferred. For example, a teletypewriter carrier signal is narrowband and therefore requires little band space. On the other hand, voice and facsimile require a much larger band than teletypewriter to accommodate most of the complex wave pattern that makes up speech. A still wider band is required for data transmission because of the very high keying rate of data signals.

b. Composite Signal. A composite carrier signal contains the signal intelligence from all the channels.

(1) FDM signals. In frequency-division multiplex, the greater the number of channels, the greater is the required bandwidth capability of equipment. In FDM a direct relationship exists between these two factors because the bandwidth of each channel takes up its portion of the overall frequency spectrum in the composite signal. Each channel signal is analog (continuous) in nature. Assuming that the equipment has adequate bandwidth capability, a theoretically limitless number of voice channels can be added because the equipment translates the individual channel frequencies to other frequencies. Thus, to add more channels, it is necessary to use more of the available frequency spectrum to accommodate the expanded composite signal bandwidth.

(2) TDM signals. In time-division multiplex, there is no direct relationship between channel numbers and composite signal bandwidth. This condition springs from the fact that TDM signals are digital in nature (pulses). The time frame which the equipment is designed to handle limits the number of channel pulses that can be accommodated. Merely increasing the frequency spectrum for the composite signal does not allow more channels to be added, because the time frame can handle only a limited number. To add more channels, it is necessary to change to a terminal equipment type that will allow the use of a different time frame.

3-9. APPLICATION OF CARRIER SYSTEMS

Carrier systems have been adapted to both commercial and military communications. In many cases, both military and commercial systems have similar applications. Generally, carrier is used in systems that are required to carry many parallel channels of information.

a. Specialized Military Applications. Most military carrier systems are designed for use in voice communications networks. Both telephone and telegraph carrier terminals have their appropriate uses in such systems. But carrier is by no means limited to these applications. Examples of specialized carrier applications in military systems include:

(1) A landline on-tone, off-tone carrier system conveys radar data between installations of an air defense system.

(2) A radio-carrier link conveys command signals to a guided missile.

(3) A radio-carrier link conveys combined telemetry signals from a satellite in orbit.

(4) Landlines or radio link carrier systems tie together headquarters elements within an area communication system. The carrier channels serve primarily as trunk lines between switchboards.

(5) Landlines or radio link carrier systems interconnect with commercial systems. Military equipment and manpower can be saved by using commercial carrier channels when they are available.

b. Fixed-Plant Applications. Carrier has found wide use in long-distance radio systems and in fixed-plant wire systems.

(1) Long-distance radio systems. To prevent interstation interference and to promote operational efficiency, receiving and transmitting sites of long-distance radio stations are separated. In an effort to reduce the number of wire pairs between these station sites, carrier is used to parallel many communication channels on the same wire pair or radio link circuit. In addition to this short-distance use of carrier, many channels of teletypewriter communication are multiplexed on the long-distance radio transmission system. This type of carrier is especially valuable in that it minimizes the need for multiple radio-frequency assignments.

(2) Fixed-plant wire carrier systems. A fixed-plant wire carrier system is usually a direct application of commercial landline carrier. Whatever techniques apply to civilian use also apply to the military.

c. Equipment Characteristics. Fixed-plant and tactical telephone carrier systems use the same general principles of operation. The principal system differences lie in equipment characteristics.

(1) Tactical carrier. Tactical carrier equipment must be kept small and light because it must be portable or mobile. It is usually set up in a "stack" arrangement so that various basic units can be applied in a building-block arrangement to expand channel capacity. Also, field conditions dictate that tactical carrier be very rugged and relatively free from weathering effects.

(2) Fixed carrier. Fixed carrier equipment is usually designed to be installed in an adequate shelter to protect against weather damage. The equipment normally is large, heavy, and cumbersome. It is designed for continuous operation over long periods of time with minimum maintenance. The equipment is arranged so that additional channels may be added, when desired, in blank panel spaces.

d. Application to Microwave Radio Systems. Microwave radio relay systems provide line-of-sight coverage between stations. When distances exceed the line-of-sight range, microwave can be adapted to troposcatter and ionoscatter transmission. One important advantage gained by operating in the microwave range is the enormous frequency spectrum space available. For example, a recent design of troposcatter equipment has sufficient bandwidth to accommodate 600 FDM carrier voice channels.

STUDY EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. What distinguishing characteristic of a radio system makes it different from a carrier system?

   a. Radio uses a carrier frequency below 20,000 Hz.

   b. Radio uses a method of modulation different from that used in carrier.

   c. Intelligence is separated from the carrier during the demodulation of a radio wave.

   d. The carrier used in a radio system is higher in frequency than that used in a carrier system.

2. Low-frequency carriers are usually transmitted over wire or cable facilities because

   a. the bandwidth is very large.

   b. they will not radiate.

   c. they can carry many messages.

   d. channel separation is required,

3. One characteristic of a radio communication system is that

   a. frequencies have no bearing on distance coverage.

   b. a frequency assignment must be made for each RF channel used.

   c. it requires less transmitting power than a landline carrier system.

   d. there is no danger of power loss due to undesirable radiation from the transmission line.

4. The electrical characteristics of the interconnecting line of a carrier communication system largely determine the efficiency of transmission. Line loss is due primarily to

   a. radiation.
   c. attenuation.

   b. absorption.
   d. intermodulation.

5. The integrated communication system shown in figure 3-1 is built up by starting first with the radio system and then successively adding

   a. telephones, telegraph carrier, teletypewriters, and telephone carrier.

   b. telephone carrier, telephones, telegraph carrier, and teletypewriters.

c. telegraph carrier, teletypewriters, telephone carrier, and telephones.

d. teletypewriters, telephone carrier, telephones, and telegraph carrier.

6. It is characteristic of a frequency-division-multiplex carrier system that each channel

a. uses a discrete wire pair.

b. operates on a separate and discrete frequency.

c. uses a common carrier frequency for modulation of all channels.

d. shares the line with every other channel in the system on a time-sharing plan.

7. The practical limit to the number of channels that can be transmitted by a telephone carrier system over a landline or cable is the

a. total attenuation of the cable.

b. output power available from the terminals and repeaters.

c. overall frequency response of the cable and its facilities.

d. number of repeaters needed to compensate for line attenuation.

8. When a multichannel telephone carrier signal is placed on a radio system, the bandwidth that the signal occupies in the radio spectrum depends on the

a. number of carrier channels in use.

b. power in each telephone carrier channel.

c. stability of the radio system oscillators.

d. stability of the channel carrier oscillators.

9. One characteristic of a frequency-division-multiplex receiving channel is that

a. all carrier frequencies are higher than 3,500 Hz.

b. filters are not required for channel separation.

c. the equipment is channelized by means of a sequential pulse pattern.

d. the demodulating carrier frequency must be as close as possible to the modulating carrier frequency.

10. One of the difficult technical problems in time-division multiplex is to maintain synchronization of the receiving terminal by means of the incoming signal. Synchronization is necessary, because in TDM

a. the sampling occurs at an audible rate.

b. each channel uses a highly selective filter to separate the signal frequencies.

c. each received pulse sample must be selected in sequence and placed into its appropriate channel.

d. the pulses sample the various channels without regard to a sequential time pattern.

11. The function of the equalizer in a telephone carrier terminal is to

a. level out all received signals to the same strength.

b. raise the received line signals to the required levels.

c. attenuate the highest signal frequencies and amplify the lowest.

d. transmit varying signal levels at different frequencies to compensate for line losses.

12. The function of a line repeater in a carrier system is to

a. prevent interchannel interference.

b. prevent overloading of the receiving channels.

c. compensate for loss in each unit length of line.

d. automatically compensate for changes in output level from the transmitting terminal.

13. Many channels of telegraph carrier can be included within one voice band because

a. each channel of telegraph carrier occupies a relatively narrow frequency band.

b. the low line level prevents overloading of channel amplifiers.

c. each channel operates on a separate carrier frequency.

d. telegraph carrier channels require no equalization.

14. Four types of signals that are to be sent over a carrier system include: teletypewriter, voice, facsimile, and data. The signal requiring the widest bandwidth during transmission is

a. voice.

b. data.

c. facsimile.

d. teletypewriter.

15. Theoretically, the bandwidth of a composite frequency-division-multiplex signal may be expanded by the equipment to accommodate any number of channels through the process of

a. varying the length of each time frame.

b. adding pulses to the time frame.

c. keying the signal at a fast rate.

d. translating channel frequencies.

16. Carrier systems generally are required to carry many parallel channels of information. In most military carrier systems, the channel information consists of

a. voice or teletypewriter messages.

b. telemetry signals.

c. on-tone, off-tone messages.

d. guided missile command signals.

17. An area communication system makes extensive use of carrier equipment. The primary function of a carrier channel in such a system is to serve as

a. trunk lines between unit switchboards.

b. trunk lines between air defense stations.

c. local lines between switchboards and telephones.

d. local lines for control of guided missile firing operations.

18. The equipment in a fixed-plant carrier telephone system is similar to that used in a

a. mobile system.

b. portable system.

c. tactical system.

d. commercial system.

19. One of the characteristics of fixed-plant carrier equipment is its

a. small size.

b. light weight.

c. low power consumption.

d. need to be protected against weather.

20. Why does microwave transmission have the capability to handle a large number of traffic channels?

    a. There is no interference problem.

    b. Very low power is normally needed.

    c. Enormous frequency spectrum space is available.

    d. Directive antennas concentrate radio energy into beams.

CHECK YOUR ANSWERS WITH LESSON #3 SOLUTION SHEET, PACE 48.

LESSON 4

RADIO COMMUNICATION

SCOPE	Communication without wires; significance of frequencies; principles of radio communication; AM and FM operating principles; introduction to single sideband.
CREDIT HOURS	1
TEXT ASSIGNMENT	IT 11-180-8; Attached Memorandum, para 4-1 thru 4-4
MATERIALS REQUIRED	None
SUGGESTIONS	Review frames 41 thru 49 in IT 11-180-8, then study the Attached Memorandum.

LESSON OBJECTIVES

When you have completed this lesson, you should:

1. Know that a radio communication system includes a radio transmitter, radio receiver, and connecting radio waves.

2. Know that the primary difference between ac waves is their frequencies.

3. Know that the characteristics of a radio receiver must be compatible with the type of signal being received.

4. Be able to calculate wavelength of a radio wave when frequency is known.

5. Be able to identify frequency bands of the spectrum by frequency ranges.

ATTACHED MEMORANDUM

4-1. COMPONENTS Of A RADIO COMMUNICATION SYSTEM

a. General. As you have learned, any basic communication system consists of three parts: a source of energy, a transmission path for that energy, and a receiver capable of utilizing the energy. To be useful, the communication system must be capable of transmitting some form of intelligence. Imagine that someone is shining a flashlight beam across a darkened room toward you. You are aware that a light is shining, and perceive the light's location, but that is about all. If, however, the person holding the flashlight turns it on and off in a prearranged code, then his pattern of intelligence is being transmitted; a useful communication system is thereby established. We might say that the intelligence is modulating the energy source.

b. Radio Communication System. A radio communication system is similar in principle to the simple flashlight analogy. However, since humans cannot sense the presence of radio waves, special devices that are sensitive to radio energy must be used.

(1) In the lesson on telephone communication, we learned that direct current from a battery is modulated by voice energy from the person speaking into the microphone. Since direct current serves as the medium of intelligence transfer, a wire must be used to convey the current and its impressed intelligence to the distant receiving earpiece.

(2) Radio communication is more complex than telephone communication because the connecting wire is missing. Some means other than a wire must therefore be found to convey the intelligence. The solution to this problem establishes the need for a radio transmission path.

(3) Suitable sending and receiving devices must be placed at the terminations of the radio transmission path. A radio transmitter generates and modulates the radio signal, and a transmitting antenna radiates the energy. The radio receiver at the distant end of the transmission path receives and demodulates the signal picked up on its receiving antenna.

(4) A further complication lies in the fact that each radio signal must be assigned its distinct place in the radio-frequency spectrum. Since there are literally thousands of radio stations, it follows that each radio transmitting station must generate and radiate its signal at one specified frequency, or a conglomeration of received intelligence will result. When this happens we have a situation analogous to a telephone system without a switchboard; everyone hears everyone else simultaneously. Moreover, since each radio transmitting station operates on its assigned frequency, each radio receiving station must be suitably equipped to select the one radio signal it needs from the great gamut of signals that impinge upon the receiving antenna.

c. Basic System. In the basic radio communication system shown in block form in figure 4-1, a radio transmitter is used to develop and process the RF waves which are to be radiated into space. The simplest radio transmitter consists of an oscillator stage which generates the RF carrier signal. Usually, however, the comparatively weak output of the oscillator is applied to one or more amplifier stages which increase the transmitter output power to a more desirable level.

d. Modulation. If the transmitter is to radiate energy containing intelligence, a device must be used to control the transmitter output. A radio wave controlled by the intelligence signal is called a modulated radio wave. A telegraph key is used to control the waves radiated from a radiotelegraph transmitter. When the key is closed, an RF signal is radiated. When the key is open, the RF signal ceases. In this way, a message in a telegraphic code consisting of dots and dashes is transmitted. If speech intelligence

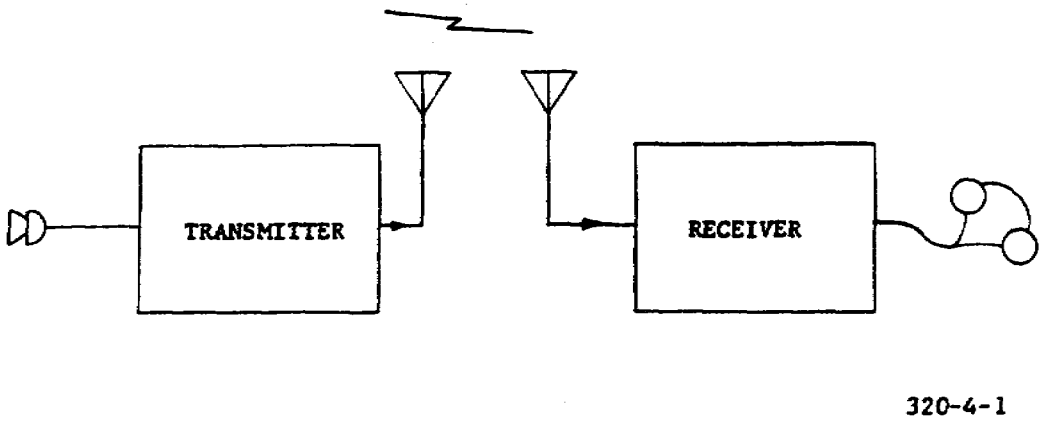

Figure 4-1. Block diagram of a basic radio communication system.

is to be transmitted, a microphone must be used to control the output of the modulator and, hence, the transmitter output. Such a transmitter is called a radiotelephone transmitter.

e. Radiation. The output of the transmitter is applied to the transmitting antenna whose primary function is to radiate the energy into space in the form of electromagnetic waves.

f. Reception. A radio receiver has a triple function. First, it selects the desired signal from the great number picked up by the antenna. Secondly, it removes the intelligence from the RF signal. Thirdly, it amplifies the audio-frequency (AF) output which in turn causes the loudspeaker to reproduce the sound. Between the signal selection and detection stages there usually will be an amplifier to raise the weak signal to a higher voltage.

4-2. METHODS OF TRANSMISSION

a. Carrier Wave. The radio signal produced by a transmitter at a fixed frequency is known as the carrier wave, or simply carrier. It carries no intelligence until it is modulated or changed in accordance with the intelligence to be transmitted. Upon modulation, it changes in a manner to suit the characteristics of the equipment used in the system.

b. Radiotelegraph. Radiotelegraph signals are produced by keying a continuous-wave (CW) carrier. The telegraph key turns the transmitter on and off, resulting in "bursts" of RF signals in accordance with the telegraph message. The RF signal, being of too high a frequency for the human ear to detect, is made audible in the receiver by mixing the incoming CW signal with a signal generated locally by a beat-frequency oscillator (BFO). Since both incoming and BFO signals are in the RF range, they are inaudible. However, the combination of the two produces a third signal, which is audible. Thus each time the key is depressed at the transmitter, a tone is heard from the receiver headset.

(1) Intelligence is conveyed from transmitter to receiver by means of the international Morse code. CW transmission uses a very narrow

bandwidth, which limits noise interference. This is the primary reason that CW signals can be received at greater distances than are possible with the same power by other means of radio transmission.

(2) The manual CW system is normally a slow method of transmission and reception. Its speed is limited primarily by the skill and experience of the operator. This transmission rate may be extended by adapting automatic transmitting and receiving devices to the CW radio system.

(3) If a keyed tone signal is impressed on the carrier at the transmitter, the process is called tone modulation. A BFO is not needed to receive tone-modulated radiotelegraph signal pulses; a BFO is needed to receive CW signals.

c. Radiotelephone. Two commonly used methods of modulation in radiotelephone transmission are amplitude modulation (AM) and frequency modulation (FM). In either system, a microphone converts voice waves or other sound waves to weak electrical impulses. These impulses are strengthened through a series of amplifiers. A modulator serves to combine the AF with the RF carrier. The form of modulation (AM or FM) determines to a large extent the signal characteristics.

(1) Amplitude modulation. In AM, the modulator heterodynes the AF signal with the carrier signal of the radio transmitter. This process results in development of a radio wave that maintains a fixed carrier frequency but varies in amplitude according to the AF signal amplitude and frequency. The amplitude variations are caused by the addition of intelligence power in the form of upper and lower sidebands. The carrier itself contains no intelligence. This is a double-sideband (DSB) composite radio signal.

(2) Single sideband. Single-sideband (SSB) transmission is a special form of AM wherein only one sideband is transmitted. The carrier and other sideband are suppressed. This form of transmission is possible because identical intelligence appears in both upper and lower sidebands. By eliminating the carrier and one sideband, SSB transmitters can produce the same intelligence as AM with a much smaller output power. A further advantage is gained by the reduction of the composite signal bandwidth to one-half its former value for DSB transmission. Since the carrier has been suppressed, it is necessary to furnish a locally generated carrier in the receiver to achieve demodulation.

(3) Frequency modulation. In FM, the modulator causes the signal frequency to shift to either side of the resting frequency (frequency of the carrier without modulation). The deviation from resting frequency follows the amplitude and frequency patterns in the AF signal. The overall RF signal has a relatively constant amplitude value, but varies in frequency in accordance with the signal intelligence placed on the carrier during the modulation process.

d. Radio Teletypewriter. Radio teletypewriter (radiotelegraph) signals are produced by a complex system of mechanical and electronic equipment.

Each time that a key on a teletypewriter keyboard is depressed, the keyboard automatically produces a series of measured pulses (marks) and pauses (spaces) with a different sequence for each letter of the alphabet. This coded series of pulses may be used to key a radio transmitter in a number of different ways, depending on the type of transmitter, receiver, and teletypewriter equipment.

(1) In one method, the mark is made by turning on the carrier, and the space is made by turning off the carrier. It is characteristic of this on-off system that background noise may increase during the time the spacing impulse (no signal) is being sent.

(2) A very widely used radio communication system for single-channel operation is known as frequency-shift-keying (FSK), a system in which the carrier frequency is shifted back and forth between two distinct frequencies. The mark is sent at one frequency and the space is normally 850 Hz from the mark frequency. The superiority of this system over the on-off system is that the continuous presence of a radio signal on either marks or spaces reduces noise buildup.

e. Radio Facsimile. Radio facsimile (fax) is a method of transmitting pictures, maps, sketches, and written or printed material by means of radio signals.

(1) In the transmitting system, the subject matter, or copy, is wrapped around a drum which revolves at a constant speed and progresses a uniform amount on a drive shaft with each revolution. By this movement, different parts of the copy are exposed to a sharply focused beam of light. This light beam is reflected from the copy and passes through another focusing lens to a photoelectric tube, where varying amounts of light from the corresponding white and black portions of the copy are changed to electrical signals. This process is called scanning. Electrical signals produced by fax equipment may be transmitted over any radio or wire channel suitable for voice transmission.

(2) The receiving system also uses a similar scanning arrangement, but the process is reversed. The received signals of varying intensity control the intensity of a light beam playing on a photographic negative wrapped around a drum. This receiving drum has the same physical dimensions, rate of speed, rotation, and axial movement as the one used at the transmitter. In addition, the receiving drum rotation is synchronized with the rotation of the transmitting drum.

f. Television. This method of communication instantaneously reproduces at a distance, by means of an electrical communication channel, visible images of actual or recorded scenes. The scanning process is similar to that of fax, except that the scanning occurs at a very much higher rate. This results in a channel that is 2,000 or more times wider than the bandwidth of a fax channel. This restricts the use of television to the very high radio frequencies where the available channel bandwidth exists. To transmit a picture by television, the optical image of the subject is divided into a series of extremely small light and dark areas. These areas are represented in the transmitted signal by individual elements that activate particles in a

fluorescent screen in the receiver. The resulting light and dark areas in the screen are integrated into a complete picture by the eye. This integration is made possible by the characteristic known as persistence of vision. As in fax transmission, synchronization of the receiving system by the transmitting system is essential for accurate reproduction of the received image.

4-3. ELEMENTS OF RADIO TRANSMISSION

The radiating effect caused by a pebble dropped into a quiet pool of water illustrates the action of radio waves. The effect of the pebble's impact is distributed to all parts of the pool by waves which radiate in circles from the spot where the pebble entered. These waves crest and fall at the same rate throughout their travel time. Radio waves from a vertical antenna act in much the same manner. Most of the energy is radiated along the ground (groundwaves), but some of it is radiated at varying angles skyward (skywaves). However, virtually none is radiated directly above the axis of the antenna because of the nature of the radiation pattern. The characteristics of radio waves are as follows:

a. Speed, or velocity, is approximately 300,000,000 meters (186,000 miles) per second, the speed of light.

b. The wavelengths of radio waves are expressed in meters or feet. The distance that the leading part of one wave has traveled when the next wave starts is the wavelength. In figure 4-2, this is indicated as the distance between the crest of the first wave and the crest of the next wave.

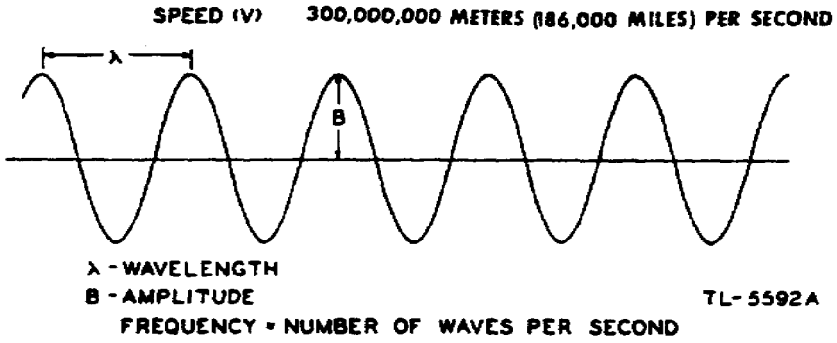

Figure 4-2. Relationship of frequency, wavelength, speed, and amplitude of- a radio wave.

c. Frequency of radio waves is expressed in Hz, kilohertz (kHz), or megahertz (MHz), and is the actual number of waves transmitted or received in 1 second. A hertz is equal to one wave in 1 second, a kHz is equal to 1,000 Hz, and a MHz is equal to 1,000,000 Hz.

d. The important relationship of speed, frequency, and wavelength is shown by the formula:

$$\lambda = V/F$$

where V is the velocity of 300,000,000 meters per second, F is the frequency expressed in Hz, and λ (Greek letter lambda) is the wavelength in meters. As the frequency rises, the wavelength shortens. This relationship is graphically expressed in figure 4-2. The free-space velocity of a radio wave is nearly constant regardless of its frequency; the wavelength can therefore be found by dividing the velocity by the frequency of the wave.

$$\text{Wavelength (meters)} = \frac{300,000,000}{\text{frequency (Hz)}}.$$

Example 1: Find the wavelength in meters for a frequency of 3,000 kHz.

$$\lambda = V/F - 300,000,000/3,000,000 = 100 \text{ meters.}$$

When the wavelength is known and it is desired to find the frequency, the velocity is divided by the wavelength.

$$\text{Frequency (Hz)} = \frac{300,000,000}{\text{wavelength (meters)}}.$$

Example 2: Find the frequency in MHz for a radio wave 30 meters long.

$$F = V/\lambda = 300,000,000/30 = 10 \text{ MHz.}$$

e. The amplitude, or strength, of the radio wave is expressed in volts. It represents the height of the wave as expressed by the distance B in figure 4-2.

f. Two unmodulated RF signals having similar amplitudes but different frequencies are compared in figure 4-3. Both the 2-MHz and 10-MHz signals have the same waveform. The significant difference is the greater number of cycles in the 10-MHz signal over the same period of time. This figure illustrates the fact that a low-frequency signal has a longer wavelength than a high-frequency signal.

g. The power radiated is the amount of electrical energy, expressed in watts, radiated by a transmitting antenna.

4-4. COMMUNICATION FREQUENCIES

a. Meaning of Radio Wave. A radio wave is an alternating current (ac) of high frequency. The frequencies that can be used for communication purposes may be conveniently divided into two broad groups: AF and RF.

b. Audio Frequencies. Audio frequencies are those frequencies that lie between 20 and 20,000 Hz which the human ear can hear. For all practical purposes, the AF range includes those frequencies between about 50 and 15,000 Hz.

(1) The frequencies that are most important in rendering human speech intelligible fall in the range from approximately 300 to 3,500 Hz. A voice channel must therefore pass at least this frequency range.

(2) In music the range is considerably wider. The fundamental range of a pipe organ is from about 16 to 5,000 Hz, and the highest fundamental note of the flute is about 4,000 Hz.

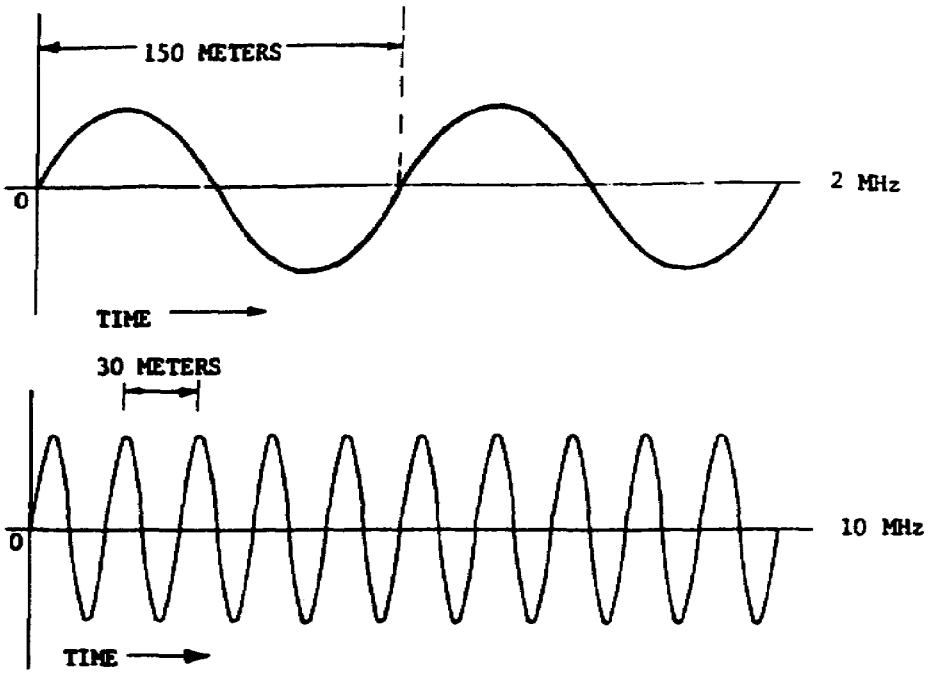

Figure 4-3. Wavelengths of two radio waves of different frequencies.

(3) Speech and music actually include very complicated combinations of frequencies of irregular and changing shapes called harmonics or overtones. These are multiples of the fundamental tone, or frequency, and give individual characteristics to sound of the same fundamental frequency coming from different sources.

(4) Experiments indicate that the human ear can best hear sounds of about 2,000 Hz. Sound waves around 15,000 Hz and higher, such as those set up by very high-pitched whistles, are often inaudible to adults. Frequencies below 20 Hz (such as the staccato tappings of a woodpecker) are recognizable more as individual impulses than as tones.

(5) Although audio frequencies are too low to provide effective radiation, they nevertheless play an important part in radio communication. As electrical signals, they operate telephone receivers, loudspeakers, and other electromechanical devices which produce sound waves we can hear.

c. Radio Frequencies. Radio frequencies extend from about 20 kHz (20,000 Hz) to over 300,000 MHz (300 billion Hz). Since different groups of frequencies within this wide range produce different effects in transmission, radio frequencies are divided into groups, or bands, of frequencies for the convenience of study and reference. The higher we extend the range of useful radio frequencies, the more spectrum space we will have for our use. This is the primary purpose for research and development leading to use of the higher frequencies of the radio spectrum.

LESSON EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. A radio transmitter is made up of combinations of individual stages. The basic stage found in every radio transmitter is

   a. a keyer.
   b. a modulator.
   c. an amplifier.
   d. an oscillator.

2. When a radio operator opens and closes his telegraph key, the result of his action is to

   a. turn the radio wave on and off.
   b. connect the antenna to the oscillator.
   c. feed line power into the power supply.
   d. add power to the continuously radiated RF signal.

3. The primary function of a radio transmitting antenna is to

   a. limit the transmission of radio signals to one radio receiving station.
   b. increase the range of the radio communication system.
   c. reradiate the received signals.
   d. radiate electromagnetic waves.

4. The sequence of processing a radio wave in a radio receiver is

   a. signal selection, RF amplification, detection, AF amplification.
   b. RF amplification, signal selection, detection, AF amplification.
   c. signal selection, detection, RF amplification, AF amplification.
   d. detection, RF amplification, signal selection, AF amplification.

5. An unmodulated radio wave is characterized by the fact that it

   a. sends out coded signals.
   b. has uncontrolled frequency.

c. carries no signal intelligence.

d. changes its power relationships with time.

6. How is a continuous-wave radiotelegraph signal made audible in a radio receiver?

a. The RF amplifier converts the received signal to AF energy.

b. The AF amplifier feeds back parts of its output energy to the RF amplifier.

c. The signal from a beat-frequency oscillator beats with the incoming RF signal to produce an AF signal.

d. The carrier oscillator removes the AF intelligence from the incoming RF signal.

7. The primary reason that CW signals can be heard over greater distances than signals produced by other radio communication systems is that CW transmission uses

a. low-speed keying.

b. the international Morse code.

c. a narrow bandwidth which minimizes noise interference.

d. more power in its signal peaks than any other radio transmission system.

8. Assume that a radio receiver is tuned to receive a tone-modulated signal. One stage in the communication receiver that is NOT used is the

a. demodulator.

b. beat-frequency oscillator.

c. radio-frequency amplifier.

d. audio-frequency amplifier.

9. The function of a modulator in an AM radio transmitter is to

a. heterodyne the AF signal with the RP carrier.

b. rectify the combined AF and RF signals.

c. amplify the AF microphone signals.

d. generate the RF carrier frequency.

10. Assume that a radio transmitter is sending out a mark signal on 1,725.425 kHz and the space signal will be lower in frequency. The space signal will go out at a frequency of

a. 1,724.000 kHz.
c. 1,725.000 kHz.

b. 1,724.575 kHz.
d. 1,726.275 kHz.

11. How is the process of scanning applied to facsimile transmission?

a. Reflections of the light beam cause modulation of the transmitter.

b. A constant-speed drum progresses a uniform amount along a drive shaft with each revolution.

c. A synchronizing signal coordinates drum rotation at both sending and receiving terminals.

d. The received signals control the intensity of a light beam on the receiving drum.

12. Radio waves from a vertical antenna are sometimes received over greater distances than expected. This results from the fact that a vertical antenna radiates

a. all of the energy along the ground.

b. all of the energy at an angle to ground.

c. some of the energy skyward, with most along the ground.

d. some of the energy along the ground, with most going skyward.

13. Four characteristics of a radio wave in free space are: amplitude, frequency, velocity, and wavelength. The only characteristic that remains constant is

a. wavelength.
c. frequency.

b. amplitude.
d. free-space velocity.

14. What is the wavelength of a 60-MHz radio signal?

a. 5 meters
c. 50 meters

b. 10 meters
d. 100 meters

15. How do the two radio signals shown in figure 4-3 differ?

a. They have different waveforms.

b. Their velocities are not the same.

c. Their frequencies are not the same.

d. They have been modulated with different intelligence.

16. For convenience, the Army divides the radio communication spectrum into four bands. A radio wave having a frequency of 250 MHz falls into the band identified as

a. HF.
c. UHF.
b. VHF.
d. SHF.

17. The minimum requirement of a voice channel is that it must pass at least the frequencies between

a. 16 to 5,000 Hz.
b. 300 to 3,500 Hz.
c. 50 to 15,000 Hz.
d. 2,000 to 20,000 Hz.

18. When radio operators receive CW signals, they customarily adjust the receiver output tone for best ear responsiveness. This tone frequency is approximately

a. 20 Hz.
c. 2,000 Hz.
b. 200 Hz.
d. 20,000 Hz.

19. What is the reason that audio-frequency energy cannot be radiated from an antenna of practical length?

a. Mechanical vibration of the antenna wires causes power loss.
b. Audio frequency is normally too low to provide effective radiation.
c. Sufficient power cannot be placed into the signal to enable it to radiate.
d. The signal is too easily intercepted to be useful in military applications.

20. A great deal of research and development of electronic equipment is devoted to utilization of the extended microwave ranges. Extending the frequency spectrum through the microwave range is important because

a. skywave radiation improves above 30 MHz.
b. more spectrum space becomes available as we go higher in frequency.
c. commercial broadcasting using the surface wave becomes more practical.
d. over-the-horizon communication becomes increasingly useful at the microwave ranges and above.

HOLD ALL TEXT MATERIALS FOR USE IN COMPLETING SUBCOURSE EXAMINATION
CHECK YOUR ANSWERS WITH LESSON #4 SOLUTION SHEET, PAGES 49 & 50.

EXTENSION COURSE OF THE US ARMY SIGNAL SCHOOL

SOLUTIONS

SIGNAL SUBCOURSE 320 ..... Communication Fundamentals

LESSON 1 ..... Elements of Communication

All references are to the Attached Memorandum, unless otherwise indicated.

1. a--ST 11-180-8, frame 8
2. d--ST 11-180-8, frame 17, 20, and 24
3. a--ST 11-180-8, frame 24
4. c--ST 11-180-8, frame 28b
5. d--ST 11-180-8, frame 35
6. d--para 1-1
7. a--para 1-2
8. a--para 1-4
9. b--para 1-4c(2)
10. a--para 1-5a(1)
11. d--para 1-6d
12. c--para 1-6a
13. d--para 1-6b
14. d--para 1-6c(2)
15. c--para 1-6e(3)
16. c--para 1-6f(4)
17. a--para 1-6h(2)
18. a--para 1-6h(6)
19. c--para 1-6h(7)
20. d--para 1-6h(8)

EXTENSION COURSE OF THE US ARMY SIGNAL SCHOOL

SOLUTIONS

SIGNAL SUBCOURSE 320 ..... Communication Fundamentals

LESSON 2 ..... Telephone and Telegraph Communication

All references are to the Attached Memorandum.

1. a--para 2-2a
2. d--para 2-2b(3)
3. d--para 2-3a
4. a--para 2-3c
5. c--para 2-3b
6. b--para 2-3b
7. c--para 2-4a, b
8. c--para 2-4c
9. a--para 2-4d
10. b--para 2-4e
11. b--para 2-4f
12. b--para 2-5a
13. b--para 2-5a(1)
14. a--para 2-5b
15. c--para 2-6
16. c--para 2-6a
17. d--para 2-6b
18. d--para 2-6b
19. a--para 2-6c
20. b--para 2-6c

EXTENSION COURSE OF THE US ARMY SIGNAL SCHOOL

SOLUTIONS

SIGNAL SUBCOURSE 320 ..... Communication Fundamentals

LESSON 3 ..... Carrier Communication

All references are to the Attached Memorandum.

1. d--para 3-1a
2. b--para 3-1b
3. b--para 3-2a(2)
4. c--para 3-2b(l)
5. b--para 3-3a
6. b--para 3-4
7. c--para 3-3b(2)
8. a--para 3-3c
9. d--para 3-4
10. c--para 3-5, 3-6b
11. a--para 3-7a
12. c--para 3-7b
13. a--para 3-8a
14. b--para 3-8a
15. d--para 3-8b(1)
16. a--para 3-9a
17. a--para 3-9a(4)
18. d--para 3-9b(2)
19. d--para 3-9c(2)
20. c--para 3-9d

EXTENSION COURSE OF THE US ARMY SIGNAL SCHOOL

SOLUTIONS

SIGNAL SUBCOURSE 320 ..... Communication Fundamentals

LESSON 4 ..... Radio Communication

All references are to the Attached Memorandum, unless otherwise indicated.

1. d--para 4-1c
2. a--para 4-1d
3. d--para 4-le
4. a--para 4-1f
5. c--para 4-2a
6. c--para 4-2b
7. c--para 4-2b(1)
8. b--para 4-2b(3)
9. a--para 4-2c(1)
10. b--para 4-2d(2)

In frequency-shift keying of a radio signal, the space is 850 Hz (0.850 kHz) from mark, in this case below it. Therefore: 1,725.425 - 0.850 = 1,724.575 kHz.

11. b--para 4-2e(1)
12. c--para 4-3
13. d--para 4-3d
14. a--para 4-3d, example 1

$$\text{Frequency (Hz)} = \frac{300,000,000}{\text{wavelength (meters)}}.$$

15. c--para 4-3f

16. b--ST 11-180-8, frame 46

17. b--para 4-4b(1)

18. c--para 4-4b(4)

19. b--para 4-4b(5)

20. b--para 4-4c

US ARMY
SIGNAL SCHOOL
FORT GORDON, GEORGIA 30905

IT 11-180-8

MEANS OF COMMUNICATION

PREPARED BY:

DEPARTMENT OF ARMY WIDE TRAINING SUPPORT

MEANS OF COMMUNICATIONS

CONTENTS

*This instructional text supersedes ST 11-180-8

OBJECTIVES

This text is for teaching yourself the various means of communication the Army uses for purposes of command and control. After reading this text, you should:

a. Know the meaning of communications.

b. Be able to identify the several means of communication.

c. Know the advantages and disadvantages inherent in each means of communication.

INTRODUCTION

This text is presented in frames. Each frame is a small bit of instruction. The frames in their sequence as numbered form a program for attaining the objectives of this text.

a. Read and Respond. As a rule, each frame requires some kind of response from you; for example, filling a blank space with the correct word or words, or selecting the correct completion response from two or more choices appearing in parentheses. A few frames require no response, but contain information you must read. Such an information frame relates to subsequent frames that do require responses; so read each information frame. As you read, we recommend that you place a sheet of paper or a piece of cardboard over the next frame below the one you are reading to cover the frame answers.

b. Check Each Response. After you complete a frame, advance to the next frame and check your response against the desired response (the correct solution); they should be the same or very nearly so. Then go on to the next frame.

c. Read Summary and Complete the Self-Test. After you finish all the frames, read the summary. Next, take the self-test. Finally, check your answers to the self-test against the solutions.

PROGRAMMED INSTRUCTION

---

1. A means of communication is a medium by which a message is conveyed from one person or place to another. To communicate, there must be at least two persons, a message, and a _____ .

(1. Answer: means (or medium))

2. The means of communication include radio of all types, wire lines, messenger, couriers, trained animals, mail, and visual or sound devices. Radio, wire, messenger, visual, and sound are means of _____ .

(2. Answer: communication)

3. Broadly speaking, all of the specific methods fall under either of two categories of means, namely telecommunications and physical means. Any transmission, emission or reception of signs, signals, writings, images and sounds or information of any nature by means of wire, radio, visual or other electromagnetic system is tele _____ . Obviously, the mail, a messenger, a courier, or a trained animal (such as a pigeon) that delivers a message is a p _____ means.

(3. Answer: telecommunications, physical)

4. In this text we will discuss all of the telecommunication means, but of the physical means we will discuss only the messenger. In tactical communications we are concerned primarily with _____ as a physical means.

(4. Answer: messenger)

5. The primary means used in tactical communications are R_____,
W_____ , M_____ , V_____ , and S_____·.

(5. Answer: Radio, Wire, Messenger, Visual, Sound)

6. Radio end wire means may be classified together and called electrical/
electronic means. Communications using radio or wire, or a combination of
the two, is known as _____ / _____ means.

(6. Answer: electrical/electronics)

7. The primary means of communication used in the combat zone are

a. _____ / _____ , which includes _____
and _____ .

b. _____ .

c. _____ .

d. _____ .

(7. Answer: electrical/electronics, radio, wire, messengers, visual,
sound)

8. In tactical operation, no single means is beet for communicating under
all conditions or in all situations. Each means has its own capabilities and
limitations. If you are aware of the advantages and the disadvantages each
means typically offers, you will be better able to employ the means that will
be the most likely to get the message through, without compromising it to the
enemy, and in the least possible time. In other words, the means employed in

any given situation should he whatever gives the maximum reliability, security, and speed with a minimum of effort and materiel. Effective communications should be rapid, but the first and foremost requirement is that they be r _____ and s _____ .

(8. Answer: reliable, secure)

9. Messenger communication is one of the primary means of communication used in tactical operations. Messenger continues to be the most secure means available to all units. It is the most effective method for transmission and delivery of lengthy messages and bulky items. The efficiency of messenger communications depends on the selection and training of the messengers. This means is flexible and reliable. Its speed depends on the mode of travel, the tactical situation, the terrain, and the trafficability of routes. Limitations include vulnerability to enemy action in forward areas and the lack of person-to-person conversation.

Messenger is a _____ , _____ ,and _____ means of communication.

(9. Answer: secure, flexible, reliable)

10. Messenger service may be scheduled with messengers making periodic runs over a given route along which are regularly scheduled stops at certain headquarters. Nonscheduled messenger service on an as-needed basis employs messengers referred to as special messengers. A messenger who follows a schedule and uses a motor vehicle in inking deliveries and pickups is a _____ _____messenger. If he is called upon

at any time to carry a message by air, he is a _____

_____ messenger.

(10. Answer: scheduled motor, special air)

11. If a messenger travels on foot to make deliveries, he is a foot messenger. If he makes deliveries by aircraft, he is an _____ messenger. If he uses a motor vehicle on the route he travels, he is a _____ messenger.

(11. Answer: air, motor)

12. The type of messenger who travels at the slowest rate of speed normally is the _____ messenger, whether scheduled or special. He would be good for (short/long) -distance runs.

(12. Answer: foot, short)

13. Name the six types of messengers that may be employed.

scheduled _____ _____ messengers

_____ _____ messengers

_____ air _____ messengers

_____ _____ messengers

_____ _____ messengers

_____ air _____ messengers

(13. Answer: scheduled foot, scheduled motor, scheduled air, special foot, special motor, special air)

14. The main advantages of messenger as a means are _____ , _____ , and _____ .

(14. Answer: security, reliability, flexibility)

15. You can use sound to attract attention, transmit prearranged messages, and spread alarms. You may even send messages in international Horse code by the _____ signals these devices generate. Devices commonly used in communicating with sound include: horns, sirens, bells, whistles, voice amplifiers, and explosives.

(15. Answer: sound)

16. Name six devices employed for sound communications.

_____ _____

_____ _____

_____ _____

_____ _____

(16. Answer: horns, whistles, sirens, bells, voice amplifiers, explosives)

17. When using sound to communicate, you must keep messages short and simple. Battle noise reduces the effectiveness of sound signals. Such signals are good only for relatively (short/long) distances, and are vulnerable to enemy interception.

(17. Answer: short)

18. Security, distance, enemy situation, and message length are considerations as to whether _____ communications will "get the message through."

(18. Answer: sound)

19. Visual signaling is another means of communication available to all units. An advantage of _____ communication is that it is readily _____ .

(19. Answer: visual, available)

20. Visual signaling employs flags, lights, pyrotechnics, panels, arm-and-hand signals, aircraft maneuvers, end any other devices or techniques prearranged to be sighted or seen by those for whom messages are intended. Such means are suitable for transmitting prearranged messages rapidly over short distances, and for recognition and identification of friendly forces. Visual signals are easily misunderstood and are very vulnerable to interception. In addition, the enemy may use similar signals for purposes of deception and confusion. Their use is restricted during poor visibility or when line-of-sight locations are not available, and may be prohibited for security reasons. Visual communications are particularly useful when radio silence must be imposed, in reconnaissance operations, and in situations requiring special control. Visual signals are easily _____ and vulnerable to _____ , _____ ,and _____ .

(20. Answer: misunderstood, interception, deception, confusion)

21. Flags can be used to transmit international Morse code characters and other wigwag or semsphoric representations during daylight hours. International Morse code can be transmitted in daytime by using _____ .

(21. Answer: flags)

22. Lights are used for signaling as prescribed by the commander or by the unit's Communications-Electronics Operation Instructions (CEOI). You may use flashlights, headlights, or practically any other kind of light-even infrared devices-- for sending code or giving prearranged messages in a wide variety of tactical operations. A nighttime means of transmitting Morse code message is _____

(22. Answer: lights)

23. Pyrotechnics contain chemicals that produce a smoke or a brilliant light when burning. Good for identifying friendly units, controlling fire, marking targets, and reporting locations, pyrotechnics come in various colors. Their effective use calls for preplanning. Pyrotechnics can transmit certain messages speedily to large bodies of troops and to isolated units. Normally the unit CEOI covers the meanings and uses of _____ signals.

(23. Answer: pyrotechnic)

24. Panels in bright fluorescent colors mark positions and identify units. Black and white sets of panels, for use on light and dark backgrounds respectively, enable you to send brief messages. The panel system and the

panel recognition code normally will be found in your unit CEOI. Thus, you consult your unit _____ if you are going to communicate by using _____ .

(24. Answer: CEO] panels)

25. Panels, flags, lights, and colored flares are just a few specific examples of _____ communication means.

(25. Answer: visual)

26. Name six different visual means.

_____ _____

_____ _____

_____ _____

(26. Answer: flags; lights, panels, pyrotechnics or flares, arm-and-hand signals, aircraft maneuvers)

27. One advantage of visual means is that they are readily _____ But such means do have the disadvantages of being easily _____ and _____ .

(27. Answer: seen, misunderstood (or confused), intercepted)

INFORMATION FRAME

28. Wire and radio circuits, or paths, serve as tie fundamental media of all electrical/electronics communications. The terminating, or subscriber, equipment allows us to further categorize electrical/electronics communications as voice, telegraphy, teletypewriter, facsimile, television, and data.

a. Voice includes telephone and radiotelephone voice radio. Voice allows direct communication between two or more individuals.

b. Telegraphy, as used in present-day tactical communications, is a method of transmitting messages in international Morse code over radio. Continuous-wave (CW) transmissions often are the answer to problems of distance and interference. Message rate is rather slow: 10 to 15 words per minute.

c. Teletypewriter is a rapid method of transmitting written messages over wire circuits or radio circuits. Teletypewriters operate at a rate of 40 to 100 words per minute, depending on equipment capability and operator skill. Most communications centers make teletypewriter service available.

d. Facsimile is a method of transmitting graphic material, such as photographs, maps, and map overlays. Facsimile is a relatively slow way of transmitting such matter, and it takes skilled operators and high-quality voice circuits. Normally it is employed on a point-to-point basis to meet a specific requirement.

d. Television is an electronic method of transmitting a combination of audio and graphic information. It is virtually an instantaneous one-way system since information is transmitted at one point and received at another simultaneously. Requiring expensive, complex terminal equipment and broadband circuits, television is a specialized system specifically designed to meet special requirements such as visual display in a tactical operations center.

f. Data is an electronic method of rapidly transmitting digital and analog information used primarily for fire control, meteorological, and automatic data processing systems.

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29. All electrical/electronic means carry messages or information over paths that are called _____ , which interconnect a transmitting device with one or more receiving devices.

(29. Answer: circuits)

30. Circuits installed for the common use of all authorized users of a communication system are called common-user circuits. If the commander allocates certain circuits for the exclusive use of certain individuals or certain units, these restricted-use circuits are known as sole-user circuits. Thus

there are two types of circuits in a communication system: namely

_____ and _____ .

(30. Answer: common-user, sole-user)

31. Whenever you communicate by radiotelephone or by telephone, you are using the electrical/electronic means identified as _____ communication.

(31. Answer: voice)

32. The two different electrical/electronic methods for transmitting pictures are _____ and _____ . The faster of the two is _____ .

(32. Answer: television, facsimile, television)

33. Data communications will be employed to transmit information in analog or digital form for use in automatic data processing, meteorological, and _____ _____ systems.

(33. Answer: fire control)

34. Messages can be transmitted over radio or wire circuits and printed at the rate of 40 to 100 words per minute if the means employed is _____ .

(34. Answer: teletypewriter)

35. Now, to sum up, give the six electrical/electronic communication methods.

_____ _____

_____ _____

_____ _____

(35. Answer: voice, telegraphy, teletypewriter, facsimile, television, data communications)

36. Wire is a very dependable means. It includes the use of field wire, wire-laying and recovery equipment, cable, battery-operated and sound-powered telephones, switchboards, teletypewriters, multiplexers and other associated or terminal equipment. When properly installed end employed, these items form a means that is one of the most _____ a distinct advantage.

(36. Answer: dependable or reliable)

37. Wire communications are more secure than radio communications. Transmission is confined to wire rather than being radiated into space for anyone's receiver to pick up. This fact represents an advantage/disadvantage of wire.

(37. Answer: advantage)

38. Wire communications, however, are not completely secure. The security of classified information is never assured when it is transmitted in the clear over wire circuits. The employment of wire communications reduces the probability of intercept by the enemy, but you should NOT consider wire as a _____ means of transmission unless the circuits are approved by proper authority for the transmission of _____ information.

(38. Answer: secure, classified)

39. The decision to establish wire communications depends on the need for them, the time available to install and use them, and the capability to maintain them. The supply of wire on hand, the expected resupply, and the future needs must be considered. In other words, whether to use wire is largely a question that rests on the _____ , _____ available, and capability.

(39. Answer: need, time, maintenance)

40. Although it may take longer to install wire communications than other means, wire systems can increase communication reliability by serving as an alternate means. Having an _____ means enhances the _____ of communications.

(40. Answer: alternate, reliability)

41. The use of radio is (widespread) (very limited) in the Army. Radio normally is (more secure than) (as secure as) (less secure than) wire as a communication medium. Radio (suffers from) (seldom has) problems of interference. Wire lacks the (reliability) (flexibility) that radio has.

(41. Answer: widespread, less secure than, suffers from, flexibility)

42. The Army employs radio equipment that varies from low-powered voice radio sets that are lightweight and portable to high-powered multichannel radio, radio teletypewriter, radiotelegraph (CW), or voice sets of fixed stations. Practically every commander or leader has suitable radio

equipment. There is radio equipment suited to every level in the chain of command. The use of _____ has many advantages.

(42. Answer: radio)

43. Radio communications can be quickly set up for operation, can interconnect tactical echelons separated by great distances (e.g., terrain and the enemy), and can provide high-quality multichannel circuits. Radio lends itself to concepts of mobility and fast-moving, swiftly changing tactical situations. The advantages of radio are _____ and _____ .

(43. Answer: quick installation, mobility)

44. Unfortunately, radio is subject to interference from atmospheric disturbances, jamming, and transmissions from other radio stations. However, properly allocated frequencies, competent operators, and suitable site selection will minimize these (advantages) (disadvantages).

(44. Answer: disadvantages)

45. For operating together, radio sets must have a common or overlapping frequency range, be of the same type modulation, and transmit and receive the same type of signal. Thus, if two or more radio stations are to be used to form a radio net and to intercommunicate, they must operate on the same f_____ , have the same type of m_____ , and have similar or compatible s_____ .

(45. Answer: frequency, modulation, signals)

46. Radio equipment is generally identified by the frequency band in which it is designed to operate. The frequency bands the Army usually uses are:

High frequency (HF) _____ between 3 and 30 megahertz

Very high frequency (VHF) _____ between 30 and 300 megahertz

Ultra-high frequency (UHF) _____ between 300 and 3,000 megahertz

Super-high frequency (SHF) _____ between 3 and 30 gigahertz

NOTE: 1,000 megahertz = 1 gigahertz

The abbreviations for the four bands or frequencies commonly used in radio communications are _____ , _____ , _____ , and _____ .

(46. Answer: HF, VHF, UHF, SHF)

47. Radio is identified not only in terms of frequency or band in which it is designed to operate, but also in terms of the type of modulation it has. Radio signals may be frequency modulated (FM), amplitude modulated (AM), or phase modulated (PM), depending on how the equipment is designed to function. The three possible types of radio modulation are

_____modulation,

_____modulation,

_____modulation.

(47. Answer: frequency, amplitude, phase)

48. Host radio communication systems in use today are either FM or AM. However, some of the newer radio equipment features what is called single-sideband transmission, which is related to AM. Such equipment is often referred to as SSB or _____ _____ radio.

(48. Answer: single-sideband)

49. What frequency bands do Army tactical radio communications employ mostly? Name them.

_____

_____

_____

One type of modulation is phase modulation; two other types of modulation are _____ modulation and _____ modulation.

(49. Answer: High frequency or HF, very high frequency or VHF, ultra high frequency or UHF, amplitude, frequency)

SELF-TEST

MEANS OF SIGNAL COMMUNICATION

1. The device for getting a message from one person or place to another is referred to as the _____ of communication.

2. Telecommunications is a term that applies to all means of signal communications except _____ , which is a _____ means.

3. If a messenger makes his deliveries by motor vehicle on a regular route and schedule, he must be a _____ _____ _____ .

4. If a messenger is on call to make a message delivery by traveling in an aircraft at any time, he must be a _____ _____ _____ .

5. The most secure means of signal communications is _____ .

6. Bells and sirens are examples of _____ communications, a means of signal communications whose prearranged signals are good for _____ distances and _____ messages.

7. Pyrotechnics, panels, and lights are examples of _____ signaling, a means that works well if visibility is good and if prearranged messages are used and kept short.

8. The document that governs what visual signals a unit will use is the unit's _____ _____ _____ .

9. All electrical/electronic means involve circuits formed of _____ or _____ , or a combination of these two media.

10. International Morse code is sent by radiotelegraph, a mode of transmission identified by the abbreviation _____ , which stands for _____ _____ .

11. "Voice" as an electrical/electronic means uses instruments or equipment that we know familiarly as the _____ and the _____ .

12. Written messages are transmitted and printed out at about 40 to 100 words a minute by _____ another electrical/electronic means

13. Pictorial or graphic matter can be transmitted by either _____ or _____ as the electrical/electronic means.

14. Data in digital form or in analog form are transmitted by the electrical/ electronic means known as _____ communications.

15. The path of any electrical/electronic transmission is called a _____ .

16. Radio stations in a net must operate on the same frequency _____ and have the same type of _____ .

17. Radio has the advantages of being more _____ than wire, but wire is more _____ than radio.

18. Classified information should be transmitted over _____ circuits only.

19. "SSB" stands for _____ _____ , and pertains to _____ equipment that emits signals which are essentially _____ modulated.

20. If tank commanders are ordered to operate their radio sets at a frequency of 23.0 megahertz, their authorized channel is in the _____ _____ band.

ANSWERS TO THE SELF-TEST

MEANS OF COMMUNICATIONS

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1. means. Ref: frames and 2
2. messenger, physical. Ref: frame 3
3. scheduled motor messenger. Ref: frames 10 and 13
4. special air messenger. Ref: frames 10, 11, and 13
5. messenger. Re: frame 9
6. sound, short, short (or simple). Ref: frames 15, 16, end 17
7. visual. Ref: frames 19 thru 26
8. Communications-Electronics Operation- Instructions (CEOI). Ref: frames 22, 23, 24.
9. radio, wire. Ref: frames 28 and 29
10. CW, continuous wave. Ref: frame 28b
11. telephone, radiotelephone (or voice radio). Ref: frames 28a and 31
12. teletypewriter(s). Ref: frames 28c and 34
13. television, facsimile. Ref: frames 28d, 28e, and 32
14. data. Ref: frames 28f and 33
15. circuit (or channel). Ref: frames 28 and 29
16. band (or range), modulation. Ref: frame 45
17. mobile (or flexible), secure. Ref: frames 41 and 43
18. approved. Ref: frame 38
19. single sideband, radio, amplitude. Ref: frame 48
20. high frequency. Ref: frame 46